The WEATHER

E. B. DUNN

LIBRARY
OF THE
UNIVERSITY OF CALIFORNIA.

Class

"Farmer" E. B. Dunn

for Agr. Exp. station

The Weather

and

Practical Methods of Forecasting It

By
E. B. DUNN
(*Farmer Dunn*)
Ex-Forecast Official in Charge of U. S. Weather Bureau, New York, N. Y.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

NEW YORK
DODD, MEAD & COMPANY
PUBLISHERS

QC861
D9

GENERAL Corps
Agr. Exp. Station

Copyright, 1902
BY DODD, MEAD & COMPANY

First Edition published November, 1902

Preface

THERE is no subject which so fully occupies our attention and is of so much importance as "The Weather," and none so little understood. This is probably due to the fact that the study of meteorology, that branch of science under which this subject is placed, has been confined almost exclusively to the scientist, and that all works pertaining thereto have been of such a technical and mathematical nature as to prevent the layman from undertaking the study.

It has been the aim of the author to avoid all mathematics, and scientific and technical terms and present the subject in the simplest and most popular form.

Rules and methods for determining weather changes are given from a personal and practical experience of the author covering nearly thirty years.

To Gen. A. W. Greely, formerly Chief of the

116980

United States Weather Bureau, and to the Department of Agriculture, I am indebted for valuable information.

E. B. DUNN,

Ex-Forecast Official, in charge of U. S. Weather Bureau, New York, N. Y.

Contents

CHAPTER I

THE ATMOSPHERE 1

CHAPTER II

INSTRUMENTS 9

CHAPTER III

PRESSURE OF THE AIR 36

CHAPTER IV

TEMPERATURE 40

CHAPTER V

WINDS 53

CHAPTER VI

EVAPORATION AND HUMIDITY 62

CHAPTER VII

CONDENSATION AND PRECIPITATION . . 69

CHAPTER VIII

OPTICAL AND ELECTRICAL PHENOMENA OF THE ATMOSPHERE 98

CHAPTER IX

Atmospheric Disturbances 111

CHAPTER X

Local Storms 136

CHAPTER XI

Weather Maps 153

CHAPTER XII

Climate 195

CHAPTER XIII

How to Foretell Weather Changes by the use of the Barometer and Local Atmospheric Conditions . . 238

ILLUSTRATIONS.

		PAGE
"Farmer" E. B. Dunn		Frontispiece
Cistern of Mercurial Barometer Barometer Scale Mercurial Barometer		12
Aneroid Barometer, Exterior View		14
Aneroid Barometer, Interior View		15
Altitude Barometers		16
Comparison of Thermometer Scales		20
Maximum and Minimum Thermometers		23
Wet and Dry Thermometers		25
Polymeter		27
Rain-Gauge		29
Dial of Anemoter		32
Wind Vane		34
Cirrus Clouds	*facing*	70
Cirro-Stratus, Cirro-Cumulus	*facing*	76
Strato-Cumulus, Nimbus	*facing*	82
Hourly Fluctuations of Rain at New York City		83
Typical Annual Fluctuations of Rainfall		86
Cumulus, Stratus	*facing*	90
Rainbow, Figure 1		104
Rainbow, Figure 2		105
Incipient Tornado, Fully Developed Tornado	*facing*	112
Storm Formation		113
Comparative Atmospheric Vacuum at Center of Cyclone		115
Prevailing Features and Outline of a General Cyclone		117
Movement of Air toward Center of Cyclone		119
Destruction by Broad Vortex Tornado Exploded Houses	*facing*	120

PAGE

House Turned Upside down by Tornado } . *facing* 122
House Thrown from Vortex of Tornado }
Paths of Cyclones or Low-Pressure Areas . . . 124
Paths of Cyclones or High-Pressure Areas . . . 127
Anti-Cyclone or Area of High Pressure 129
Tropical Hurricane 134
Thunderstorm Formation 147
Weather Bureau Map 157
Well-defined Areas of High and Low Pressure . . 166
Isobars Connecting Places of Equal Atmospheric Pressure 170
Isothermal Lines 171
Deflection of Wind 172
Circulation of Wind out of an Area of High Pressure into an Area of Low Pressure 173
Daily Weather Maps 178
Circulation of Wind out of an Area of High into an Area of Low Pressure 255
Maximum Temperature and Mean Temperature in the United States 340
Minimum Temperature in the United States– Local Mean Time when it is Twelve o'Clock in New York City . 341

The Weather

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

CHAPTER I

THE ATMOSPHERE

THE scientific term "Meteorology" includes all atmospheric conditions and changes. To understand the cause of these changes, it is necessary to know something of the composition of the atmosphere.

THE AIR.—The air we breathe is composed of a mixture of oxygen and nitrogen gases, a small amount of carbon dioxide, vapor of water and argon; the latter gas the latest discovery, bears a close relation to nitrogen.

DRY AIR.—Dry air comprises in proportion or essentially so, nitrogen, 78 per cent.; oxygen, 21 per cent.; argon, nearly 1 per cent.; and about .03 per cent. of carbon dioxide, by volume.

OXYGEN.—Oxygen is the life-sustaining element and varies at different times and places, the change

from the average amount being about one-half of one per cent.

Ozone is in the atmosphere in small quantities and is supposed to be produced by lightning.

Height of the Atmosphere.—It is estimated that the air which surrounds the earth extends to a height of at least fifty miles. The air of the lower part of the atmosphere is much denser than the upper part, half of the total weight being confined to the first three miles above the surface of the earth; the upper layers of air become gradually thinner and thinner, until the height of the atmosphere is reached.

Inhabitable Height.—The earth is most densely inhabited from sea-level to one thousand feet above; but it is frequently found that altitudes of 15,000 feet are also inhabited by man, regardless of the fact that the air at the higher elevation is decidedly lighter and the proportion of gases diminished according to the elevation.

Weight of Air.—The density of air at the earth's surface constantly changes, but on the average at sea-level, a cubic foot of air weighs about one ounce and a-quarter, diminishing with the elevation above sea-level.

Circulation of Air.—There is a constant cir-

culation of air flowing from the equator towards the poles in the upper atmosphere and a counter-current which flows from the poles along the surface of the earth towards the equator. The movement of air north and south is due to the high temperature at the equator and the low temperature at the poles. The warmer air ascends and flows towards the poles, while the colder air holds to the surface and flows towards the equator to take the place of the warmer air. Were it not for the continuous circulation and the excessive heating of air over various parts of the earth, which change the density of the surface air and affords an opportunity for the air to flow from place to place seeking an equilibrium, which is never attained, then our atmosphere would become stagnant and unhealthy.

Exertion of Air Pressure.—The pressure of air is exerted on everything; the amount of pressure is in relation to the height of the object above sea-level. The air pressure at the level of the sea is equal to that exerted by a column of water about 34 feet high, equal to about 1,467 pounds to the square inch.

The pressure of air is exerted equally on all sides of all objects.

Pressure of Wind.—When the atmosphere is

disturbed the wind's force gives a pressure independent of that naturally exerted on all sides of a body; it is the piling up of more air on one side of a body than on the other; when the disturbance ceases and there is a relaxation of this extra force, then the normal pressure is again assumed.

The pressure in pounds per square foot exerted by wind velocity is as follows:—

VELOCITY AND PRESSURE OF WIND.

Velocity in one hour. Miles.	Pressure on one sq. ft. Lbs.	Designation of wind force.	Velocity in one hour. Miles.	Pressure on one sq. ft. Lbs.	Designation of wind force.
1	0 01	Light.	23	2.64	Brisk.
2	0.02		24	2.88	
3	0.04	Gentle.	25	3.12	
4	0.08		26	3.38	
5	0.12		27	3.64	
6	0.18	Fresh.	28	3.92	
7	0.24		29	4.20	
8	0.32		30	4.50	High.
9	0.40		31	4.80	
10	0.50		32	5.12	
11	0.60		33	5.44	
12	0.72		34	5.78	
13	0.84		35	6.12	
14	0.98		36	6.48	
15	1.12	Brisk.	37	6.84	
16	1.28		38	7.22	
17	1.44		39	7.60	
18	1.62		40	8.00	Gale.
19	1.80		41	8.40	
20	2.00		42	8.82	
21	2.20		43	9.24	
22	2.42		44	9.68	

Velocity in one hour. Miles.	Pressure on one sq. ft. Lbs.	Designation of wind force.	Velocity in one hour. Miles.	Pressure on one sq. ft. Lbs.	Designation of wind force.
45	10.12		85	36.12	
46	10.58		86	36.98	
47	11.04		87	37.84	
48	11.52		88	38.72	
49	12.00		89	39.60	
50	12.50		90	40.50	
51	13.00		91	41.40	
52	13.52	Gale.	92	42.32	
53	14.04		93	43.24	
54	14.58		94	44.18	
55	15.12		95	45.12	
56	15.68		96	46.08	
57	16.24		97	47.04	
58	16.82		98	48.02	
59	17.40		99	49.00	
60	18.00		100	50.00	
61	18.60		101	51.00	
62	19.22		102	52.02	
63	19.84		103	53.04	
64	20.48		104	54.08	
65	21.12		105	55.12	Hurricane.
66	21.78		106	56.18	
67	22.44		107	57.24	
68	23.12		108	58.32	
69	23.80		109	59.40	
70	24.50	Storm.	110	60.50	
71	25.20		111	61.60	
72	25.92		112	62.72	
73	26.64		113	63.84	
74	27.38		114	64.98	
75	28.12		115	66.12	
76	28.88		116	67.28	
77	29.64		117	68.44	
78	30.42		118	69.62	
79	31.20		119	70.80	
80	32.00		120	72.00	
81	32.80		121	73.20	
82	33.62	Hurricane.	122	74.42	
83	34.44		123	75.64	
84	35.28		124	76.88	

Velocity in one hour.	Pressure on one sq. ft.	Designation of wind force.	Velocity in one hour.	Pressure on one sq. ft.	Designation of wind force.
Miles.	Lbs.		Miles.	Lbs.	
125	78.12	Hurricane.	138	95.22	Hurricane.
126	79.38		139	96.60	
127	80.64		140	98.00	
128	81.92		141	99.40	
129	83.20		142	100.82	
130	84.50		143	102.24	
131	85.80		144	103.68	
132	87.12		145	105.12	
133	88.44		146	106.58	
134	89.78		147	108.04	
135	91.12		148	109.52	
136	92.48		149	111.00	
137	93.84		150	112.50	

Estimated Velocity. When there is no anemometer for measuring the velocity, or if the instrument has become temporarily unserviceable, the force of wind may be estimated according to a scale of numbers from 1 to 12. The scale in most common use, especially at sea, is the Beaufort scale. Estimates on this scale at sea are made for the most part according to the commotion the wind causes in the water or the rigging of a ship. This arbitrary scale originated in the days of sailing vessels. The wind force was indicated by the various numbers according to the amount of sail that could be safely carried. The velocity in miles per hour corresponding to the different numbers has been ascertained by comparison of the estimated force on ships at sea with actual velocities observed by anemometers on shore in the vicinity at the same time.

The scale is as follows:

Wind force, Beaufort scale.	Character of Wind observed.	Velocity. miles per hour. (Approximately.)
0	Calm	0
1	Light air	3
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

Impurities in Air.—The air we breathe when exhaled, contains about five per cent. less oxygen than when taken into the lungs.

The oxygen in the air may be less than the amount exhaled, as in the rarified air of a high altitude, and still the atmosphere be in a healthy condition.

The impure air comes not only from the lungs of all animals, but from decomposition of vegetable and animal matter and from all kinds of combustion.

Carbonic Acid Gas, which contaminates the air, is found in larger quantities in the cities than in the open air of the country, and more especially in ill-ventilated school-rooms and rooms of many homes.

Ventilation.—Ventilation is as essential as the sunshine to promote health and lessen the danger from decomposed air.

Dust in the Air.—Dust in the air is composed of minute particles of vegetable and mineral matter, and a variety of substances which are in many cases injurious to health. The organic particles called microbes are most likely in the air of the sick-room and in conveyances of a public character, such as cars and steamboats, where the dust of dried expectoration impregnates the atmosphere.

Dust in the air varies at different times and places. There is less in clear than in cloudy weather; it is least over the ocean and decreases with the elevation above the earth. The largest dust particles are found near the earth's surface.

DISTANCE OBSERVABLE.—Dust particles are not as easily discernible on a cloudy day as on a day with bright sunshine. The absence of highly reflected light thus enables one to see a greater distance with the naked eye on a cloudy than on a clear day.

VISION AT SEA.—Objects are visible at sea under ordinary atmospheric conditions approximately as follows:

ELEVATION.

5 feet	= 2.99 miles	200 feet	= 18.72 miles
10 "	= 4.18 "	300 "	= 22.91 "
20 "	= 5.92 "	500 "	= 29.58 "
50 "	= 9.35 "	1000 "	= 33.41 "
100 "	= 13.23 "	1 mile	= 96.10 "

In rarified air found at high elevations the distance under similar conditions is much greater, owing to the less dense atmosphere and fewer dust particles.

CHAPTER II

INSTRUMENTS

INSTRUMENTS.—In a study of the weather for the purpose of foretelling coming changes by the means of instruments, we find the barometer the most important, the rise or fall of the mercury indicating significantly whether or not there will be a change from existing conditions, and to what extent. To the farmer and mariner the barometer is indispensable, but to use it intelligently it is necessary to have a full understanding of its mechanism and working.

PRESSURE OF THE AIR.—Atmospheric air, previously described, conforms to the law of gases and exerts an equal pressure in all directions according to its density at all elevations from sea-level to the top of the atmosphere and should have the same relative value at all places in the same horizontal layer. At sea-level the air pressure is about 1,467 pounds on every square inch of surface, which corresponds to the pressure of a column of mercury

thirty inches high. This means that a column of mercury thirty inches high will just balance the weight of a similar column of air reaching to the top of the atmosphere.

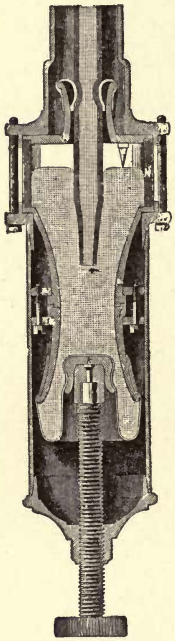
Through this medium any change taking place in the atmosphere is detected by a corresponding change in the column of mercury.

Mercurial Barometer.—This instrument is made to measure the pressure and density of the atmosphere and to detect the changing conditions. The ordinary barometer is made of a glass tube about thirty-eight inches in length, enclosed at one end, filled with chemically pure mercury, so that it balances the weight of a column of air to the height of the atmosphere, which at sea-level will be about thirty inches, the remaining space in the tube being a vacuum. The tube is placed in a cistern (also containing mercury) in a fixed vertical position. The tube after being properly arranged is enclosed in a brass tube, so cut as to expose the top of the column of mercury ; attached to one side of this opening is fastened a scale graduated in inches and hundredths of inches for measuring the rise and fall of the column of mercury according to the change of atmospheric pressure. In the middle of the brass tube is fixed a thermometer, the bulb

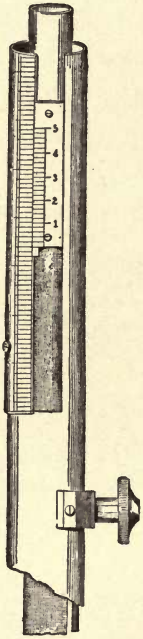
of which is externally covered, but inwardly open and nearly in contact with the glass tube. This is to indicate the temperature of the mercury in the barometer tube and not that of the external air. The central position of the thermometer is selected so that the average temperature of the whole column of mercury may be obtained, as the temperature of the barometric column is a matter of importance and must be taken into account, since mercury expands one ten-thousandth part of one inch for every degree of temperature above the 28-degree mark and a similar contraction takes place for every degree below that point; thus a correction is necessary. As the mercury in the tube just balances the pressure of the atmosphere which rests on the cistern of the barometer, it is obvious that it must rise with increased atmospheric pressure and fall with diminished pressure, so that by adjusting and reading the attached scale when it touches the top of the column of mercury in the tube, we may measure the weight of the atmosphere. The mercury which leaves the tube when the pressure diminishes necessarily goes into the cistern and is forced from the cistern into the tube when the pressure increases.

The mercurial barometer should be kept in a

room of as uniform temperature throughout the year as possible to attain the best results.



Cistern of Mercurial Barometer.



Barometer Scale.

Mercurial Barometer.

Barometers are easily injured and should not be moved after they have once been placed in position, except with the greatest care and then only after the mercury has been carefully forced from the cistern into the glass tube by an adjusting screw at

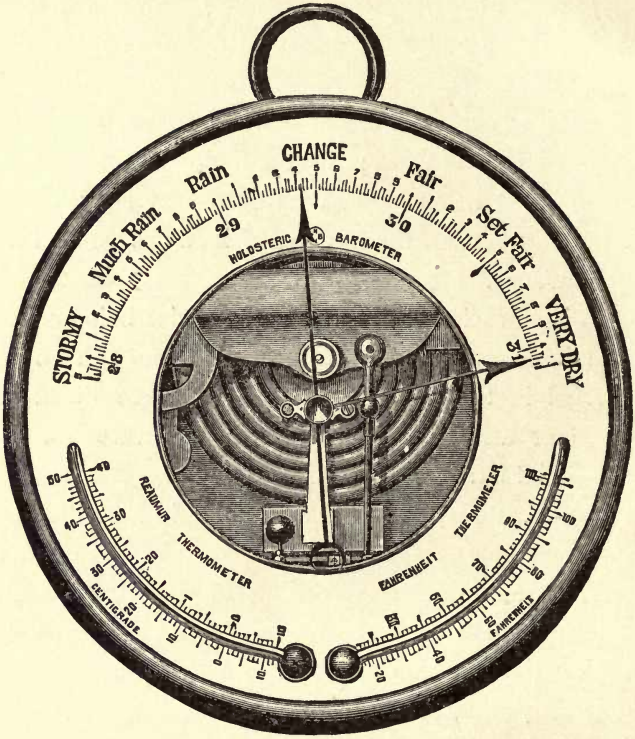
the bottom of the cistern and the barometer turned upside down and carried in that position.

ANEROID BAROMETER.—This barometer is more portable and much more easily handled than the mercurial barometer; although not considered as accurate, it has many advantages and answers for all, except scientific purposes, and has come into general use.

It is of various sizes, the average size being about five inches across; some are small enough to be carried in the vest pocket; the size has no bearing on their utility; they are useful substitutes for the mercurial barometer.

CONSTRUCTION.—It is a round thin metallic box made of corrugated German silver; as the box expands or contracts according to the atmospheric pressure upon it, a spring which is attached to levers gives motion to a needle which passes over a dial so graduated as to compare with the mercurial barometer. There is usually an outer rim to the case which carries an index hand. This hand is used to determine any change in pressure from time to time by setting it over the needle.

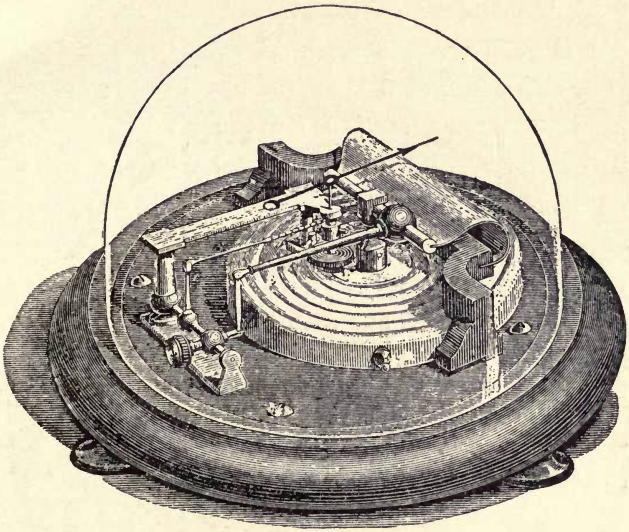
Aneroid barometers need no correction for temperature changes; they are affected, however, by decided changes and are liable to slight error.



Aneroid Barometer. Exterior view.

They should occasionally be compared with a mercurial barometer; this may be done free of cost at any station of the weather bureau.

Uses of the Barometer.—The barometer is very quick to detect changes in the atmosphere.



Aneroid Barometer. Interior view.

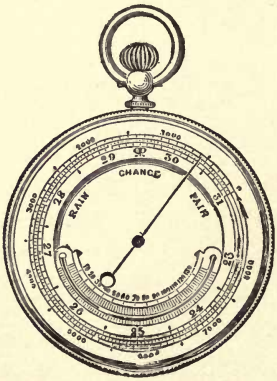
The words "fair," "rain," "stormy," on the aneroid barometer have no significance and should not be considered in regard to atmospheric changes.

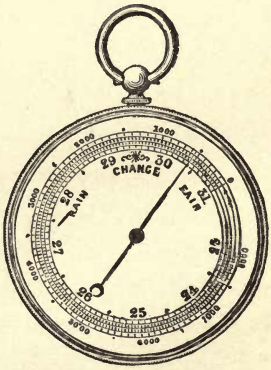
The aneroid acts quicker than the mercurial and readily indicates any sudden change which may occur in the movement of local storms.

Measurement of Heights.—As we ascend for any distance above the level of the sea the barometer falls approximately one-tenth of an inch for every one thousand feet or, to be more accurate, for every 984 feet. A corresponding rise takes

place in descending from any height. To determine any elevation above sea-level, take the reading of your barometer at 8 A. M., then write to the nearest weather bureau station for the reading of their barometer on the same day and hour (which is corrected to read to sea-level). If you find a difference of one-tenth of an inch lower in your reading, then your elevation is one hundred feet above sea-level; if the difference is one inch lower, then your elevation is practically one thousand feet. Any intermediate or greater difference in the readings between the barometers can be estimated according to these figures.

ENGINEERS' AND TOURISTS' ALTITUDE BAROMETERS.





To Determine Differences in Elevation.

If practicable, and to insure greater accuracy, the observations should be made simultaneously, either by preconcerted arrangement or otherwise, using *two* aneroids which have previously been compared with each other and the discrepancy, if any, noted.

After the readings have been made to hundredths of inches and corrected, subtract the reading made at the higher point from that made at the lower and multiply the product by 9; this will give the *difference* in altitude in feet.

Example—	30.28
	29.74
	54
	9
Difference in elevation—	486 feet.

This rule applies to atmospheric pressures near sea-level (that is, about 30 inches), and at temperatures about 50° Fahr. If the pressure or temperature is different, however, the following table should be consulted for factor to obtain more accurate results:

Mean Temperature—	Mean Atmospheric Pressure— 27 inches.	28 inches.	29 inches.	30 inches.
30° Fahr.	9.7	9 5	9.0	8.7
40° "	9.9	9.5	9.2	8.9
50° "	10.1	9.8	9.4	9.1
60° "	10.3	10.0	9.6	9.3
70° "	10.5	10.2	9.8	9.5
80° "	10.8	10.4	10.0	9.7

How to Set an Aneroid.—If your barometer does not read correctly and you know your elevation above sea-level, get a reading of the barometer from any weather bureau office at the usual hour of taking their observation, 8 A. M. or 8 P. M., make a note of your reading at that same hour, then allow for your elevation of so many inches or tenths according to the rule in previous paragraph; should you then find a difference between the readings, readjust your barometer by turning the small screw which will be found in the back of the barometer sufficiently to bring the index needle to the proper point.

Daily Change of Atmospheric Pressure.—The barometer shows a change, or, we may say, an ebb and flood tide in the atmosphere, twice daily; the highest occurs about 10 A. M. and 10 P. M., and the lowest at 4 A. M. and 4 P. M.

Annual Change of Pressure.—The average pressure shows there is a maximum air pressure in

winter and a minimum in summer over the land. Over the ocean the maximum occurs in summer and the minimum in winter.

FLUCTUATIONS OF THE BAROMETER.—Fluctuations of the barometer are greater over the ocean than over the land, except in extreme southern latitudes, where they became more uniform.

Fluctuations of the barometer are important in forecasting the weather, but to determine coming changes it requires more than a single glance at the barometer; one should have it where it may be frequently consulted. The method of forecasting the weather by use of the barometer will be described later.

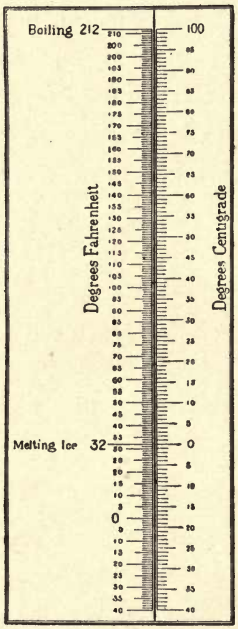
TEMPERATURE is a term used to indicate the degree of heat.

The instrument used to determine the heat of the atmosphere or other bodies is called a *thermometer.*

THERMOMETER.—Mercurial thermometers are best for all general purposes. Mercury expands evenly at all temperatures from boiling point, 212 degrees, to 39 degrees below zero at which point mercury freezes.

Alcohol (spirit) thermometers are used for recording temperatures below that at which mercury freezes.

THE SCALE.—The range of the scale varies in many makes of thermometers; on an accurately made instrument it ranges from 115 degrees above zero to twenty-five degrees below zero—which is suitable for outdoor use in almost any part of the country.



COMPARISON OF THERMOMETER SCALES.

A little study of the accompanying information and diagram will enable any one to form a clear

idea of the various thermometer scales and to convert temperatures from one scale to another.

TABLE OF FIXED POINTS.

SCALE.	Temperature of melting ice.	Temperature of boiling water.	No. of degrees between melting ice and boiling water.
Centigrade	0	100	100
Celsius	100	0	100
Reaumur	0	80	80
Fahrenheit	32	212	180

From the above it will be seen that the Celsius scale is not identical with the Centigrade, as is very generally supposed, but resembles it only in that it has the same number of degrees between the freezing and boiling points of water.

Thermometers are now, however, never graduated according to the Celsius scale, and the use of the word as synonymous with Centigrade is quite erroneous.

Only Fahrenheit and Centigrade scales are in general use, and the accompanying plate is designed to enable observers to convert temperature readings from one scale to the other without resorting to a mathematical formula.

For accurate and precise reductions between the different scales the following rules should be used:

1. To convert Fahrenheit to Centigrade: Subtract 32 and multiply by five-ninths.

2. To convert Centigrade to Fahrenheit: Multiply by nine-fifths and add 32.

3. To convert Fahrenheit to Reaumur: Subtract 32 and multiply by four-ninths.

4. To convert Reaumur to Fahrenheit: Multiply by nine-fourths and add 32.

5. To convert Centigrade to Reaumur: Multiply by four-fifths.

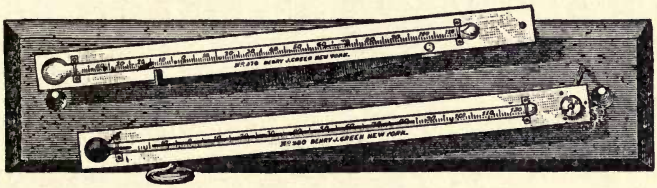
6. To convert Reaumur to Centigrade: Multiply by five-fourths.

Thermometers for indoor use have a range considerably less; usually from freezing point, 32 degrees, to 100 degrees.

It is difficult to obtain a thermometer which registers accurately at all points of the scale. Cheap thermometers are frequently found to vary from two to six degrees at nearly all points; especially is this the case in high and low temperatures. They are made to fit ready-made scales, in which the bore of the tube varies greatly.

Maximum Thermometers.—The highest temperature which occurs during the day is registered

by a thermometer with the bore of the tube near the bulb contracted, so that when the highest temperature of the day is reached and cooling begins, the thread of mercury connecting the bulb with the bore of the tube is broken, leaving the mercury in the tube at the highest point reached. By whirling the instrument the column of mercury is again united and ready for use.



Maximum and Minimum Thermometers.

MINIMUM THERMOMETERS.—The lowest temperature which occurs during the day is registered by an alcohol thermometer which has an enamel index half an inch long, fitted loosely in the bore of the tube. When the temperature falls the index is carried along the bore and the top stops at the lowest point reached, where it remains until reset by raising the bulb end of the thermometer into a vertical position, when the index slides back.

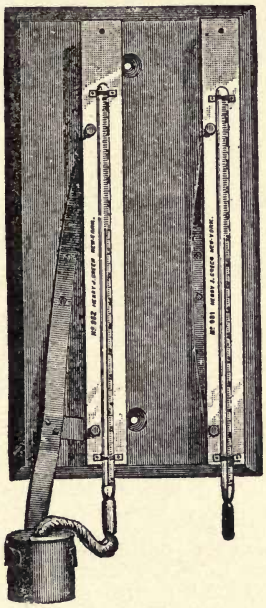
HUMIDITY.—What we understand by humidity

is that the atmosphere contains more or less moisture at all times and at all places; it is never absolutely dry. Humidity is expressed in two terms, *absolute* and *relative;* absolute humidity means the full amount of moisture present at any given time. Relative humidity means the relation of the amount of moisture present to the amount necessary to completely saturate the air. Humidity is measured in percentage. When it is said that the relative humidity is 50 per cent., this means that the atmosphere is holding just one-half of the amount it could contain at the existing temperature. As the atmosphere expands with an increase of heat, its capacity becomes greater for holding moisture, and with an increase of cold, it becomes less; so that if the atmosphere contains 50 per cent. of moisture and the temperature rises, the percentage of moisture would become less. Should the temperature fall, the percentage would become greater. The atmosphere has a capacity for holding 100 per cent. of moisture at any temperature.

Humidity, How Measured.—Two ordinary thermometers are used, placed side by side, one having a piece of thin muslin wrapped around the bulb which is kept saturated with water. The usual method is to attach one end of a piece of wick-

ing to the muslin and immerse the other end in a cup of water.

The evaporation from the muslin cools the ther-



Wet and Dry Thermometers for obtaining percentage of humidity.

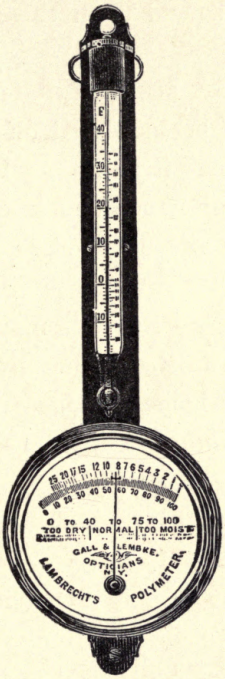
mometer bulb to the temperature of evaporation. The greater the difference between the readings of the two thermometers, the drier will be the air; the closer the readings, the more moist the air; when they read exactly the same then the atmo-

sphere is thoroughly saturated and the percentage is one hundred.

By this method it is necessary to work out each reading to determine the percentage. Where scientific precision is not necessary, I would suggest the use of an instrument called the polymeter.

POLYMETER.—This is a combination instrument, portable and easily handled, which gives the relative and absolute humidity, the dew-point and temperature on its face, without the trouble of making deductions. It is suitable for indoor or outdoor exposure. For quick work and general use it answers all purposes. It is made in Germany; the agents in this country are Messrs. Gall & Lemlike, 21 Union Square, New York city, where they may be purchased. The polymeter is of valuable assistance in making weather forecasts.

This instrument is made in brass or bronze and consists of a stem and round dial-faced surface. A thermometer is attached to the stem. At the back of the stem and partly enclosed are a number of prepared human hairs, connected with an adjustable movement at the top and bottom, and with an index hand which moves over the face of the dial according to the expansion and contraction of the hairs, which are very sensitive to moisture.



Polymeter.

RAINFALL.—A knowledge of the amount of rainfall in any locality is indispensable to the gardener and farmer, the hydraulic engineer, the builder, the merchant and many others. The health of a community, the development of the soil-products, the water supply to reservoirs, canals

and rivers,—all depend upon this important gift of nature.

Rainfall, How Measured.—The actual depth of rainfall could be measured on the ground if it would remain where it fell.

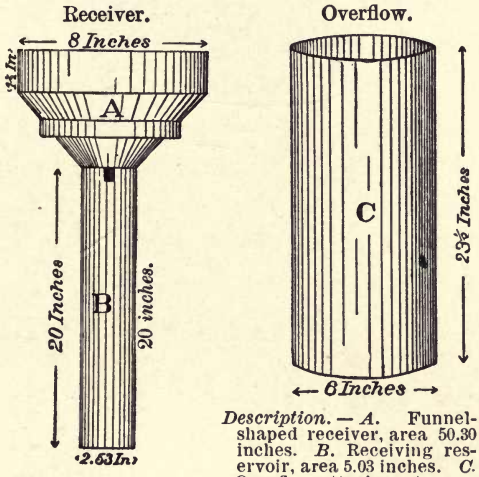
Any pan or tub would be suitable for a rain-gauge, providing the sides were vertical and of sufficient height to prevent the drops from spattering over the sides. Rainfall may be measured in this way with an ordinary rule divided into inches and tenths of inches. One inch is considered a heavy rainfall. The rain-gauge in general use is in three parts. There is a funnel-shaped receiver of galvanized iron with a vertical rim of brass; this fits over a galvanized cylinder 8 inches in diameter and 20 inches long. Placed inside of this is a brass cylinder also 20 inches long; its area is one-tenth that of the funnel.

The rain falling into the funnel runs into the brass tube. The depth of water so collected is ten times the depth of the actual rainfall. The depth is measured by inserting a thin cedar stick graduated in inches and tenths; 1 inch (10 spaces) on the stick corresponds to 0.1 (0.10 or one tenth) of an inch of rain and 1 space on the stick to 0.01 or one one-hundredth of an inch of rain.

Rain gauges should be placed so as not to be exposed to the full force of the wind and should be as near the ground as possible.

There is a very great difference in the amount of rain collected by a gauge fifty feet above the ground and one on the ground.

A fence built around a gauge three feet high and three feet distant will increase the amount collected six per cent.



Description. — *A.* Funnel-shaped receiver, area 50.30 inches. *B.* Receiving reservoir, area 5.03 inches. *C.* Overflow attachment.

Rain-gauge.

RAIN-GAUGE.—The rain-gauge consists of a funnel-shaped receiver surmounted by a cylinder 1½ inches in length and 8 inches in diameter, but

emptying into a cylindrical reservoir 2.33 inches in diameter and 20 inches in height. The area of the cross section of the reservoir is to that of the receiver as one to ten, or 1 inch of rain falling in the receiver corresponds with 10 inches of water in the gauge. The amount of rain-fall collected in the gauge is measured by means of a graduated rod on which are marked inches and tenths of inches; 1 inch (10 spaces) on the rod corresponds to 0.1 (0.10) of an inch of rain, and 0.1 of an inch (1 space) on the rod to 0.01 of an inch of rain. To provide for very heavy rainfalls the gauge is placed within an outer galvanized iron cylinder 6 inches in diameter and 23½ inches in height, and an opening is made in the top of the small cylinder of the gauge at the height of 20 inches. The gauge will then receive 2 inches (200 spaces, or 20 lineal inches on the rod) of rainfall, and when more than this falls the excess will flow over into the attached cylinder. To ascertain the amount of rain when it is in excess of two inches, first note the 2 inches in the small cylinder, then empty it, and pour into it the water in the outer cylinder; measure the amount, as already directed, add to it the 2 inches poured from the small cylinder, and the sum will be the total amount of rainfall.

Snowfall, How Measured.—A galvanized iron cylinder, 8 inches in diameter, may be used for measuring snow. Snow is usually melted and measured in the same way as rainfall; or it is measured on the ground with an ordinary rule. When melted and measured as rainfall one foot of moderately moist snow will equal about one inch of rainfall.

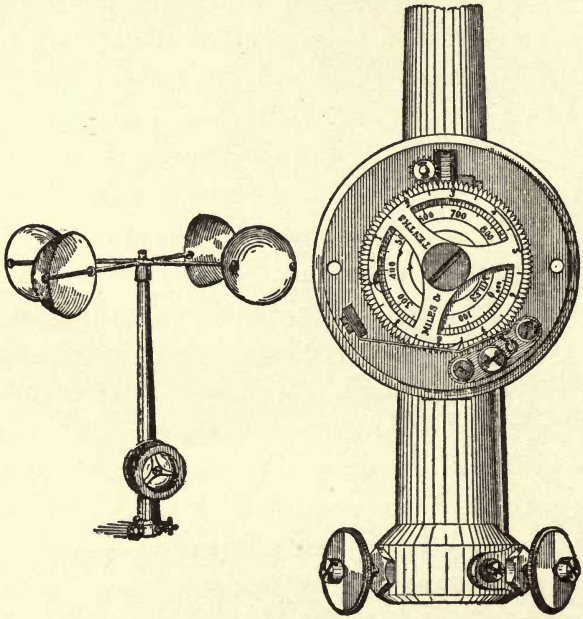
It is very difficult to get a true measurement of snowfall.

The Wind.—The disturbing element of the atmosphere. The velocity of the wind is usually measured in miles per hour. Sometimes it is determined by the pressure exerted on a flat surface held perpendicular and facing the point from which it is blowing.

Anemometer.—The instrument in general use for obtaining the velocity of the wind has four cups (half-spheres), four inches in diameter, attached to cross arms; these are fastened to a spindle connecting a system of dials, which register by the rotation of the cups, the number of miles traveled by the wind. The dials are arranged to register a mile for every five hundred turns of the spindle.

1. Dials, How Read.—The standard pattern of anemometer used by the Weather Bureau has the

registering dials mounted concentrically. The outer dial has 100 and the inner dial 99 divisions. As the dials are moved by the same wheel, they will move forward one hundred divisions in the



Dial of Anemometer. Revolutions are recorded electrically from the spring on lower side.

same time (Fig. 37). The outer dial having one hundred divisions, the inner dial will complete one revolution and its zero be one division beyond or to the left of the zero of the outer dial when the

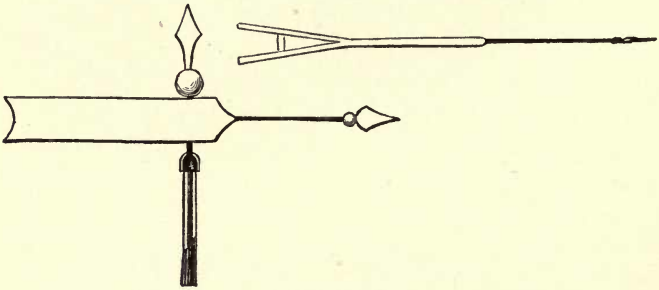
outer dial has completed one revolution, the zeros of the scales coinciding at the time the instrument was set in motion. Thus the revolutions made by the outer dial are recorded on the inner one, the number of revolutions being shown by the number of divisions of the scale on the inner dial between the zero of that scale and the zero of the outer one. In taking the reading of the anemometer at any time, the hundreds and tens of miles are read from the inner scale and the miles and tenths of miles are read from the outer one. Take from the inner scale the hundreds and tens of miles contained between the zero of that scale and the zero of the outer one, and the miles and tens of miles on the outer scale contained between the zero of that scale and the index of the instrument, and the sum of these readings will be the reading of the instrument at the time of making the observation.

2. Index Point.—The anemometer is furnished with an index point or mark on the small wheel at the top, which gives motion to the dials. This is taken as the reference point.

3. Daily Wind Movement.—The total movement for the twenty-four hours will be obtained in the following manner: Subtract the reading of the anemometer at 12 noon of the preceding day from

the reading taken at 12 noon of the current day, and the difference will be the total movement of the wind. When the reading of the anemometer is less than the reading of the preceding day, 990 miles will be added to it, and the remainder, after subtracting the reading of the preceding day, will be the total movement.

WIND VANE.—The wind vane is probably the only instrument used for determining the direction of the wind. It consists of an arrow about six feet long with a divided tail; the front half or head is



Wind Vane.

of iron, the back half or tail is of wood and split so as to form an angle; the arrow is placed upon an upright rod, and should be made to revolve without friction. The arrow points in the direction from which the wind is blowing.

The instruments here described are the only ones

necessary to keep a record of the weather conditions and up to recent years were the only ones used by the United States Weather Bureau. Since the introduction of electricity there are self-recording instruments for measuring the wind velocity, direction of the wind, amount of sunshine, the temperature, rainfall and snowfall, also self-recording barometers. Such instruments are very expensive and require constant attention to keep them in proper working order.

CHAPTER III

PRESSURE OF THE AIR

WERE it not for the fact of scientific demonstration it would be difficult to understand that the air has weight. At sea-level the pressure is fifteen pounds upon every square inch of surface, which means that each one of us bears the weight of several thousand pounds pressure but owing to nature's law causing the pressure to be equal on all sides we do not feel burdened or oppressed, the weight on one side exactly counterbalancing the weight on the other.

VARIATIONS IN PRESSURE.—Air pressure varies considerably at different places and at the same place from time to time. The atmospheric pressure would remain practically stationary, according to its weight at all places and all levels above the sea, if the heat from the sun were equally distributed and the absorbing and heat retaining qualities of the earth the same; then the heat radiated from the earth would be equal and there

would be no disturbing influence. As it is, the heat from the sun is unequally distributed, one part of the earth receiving an excess, while another part receives less than its share. The unequal distribution of heat and the unequal heat-retaining qualities of the soil are what cause quicker radiation at some places than at others; this brings about a disquietude in the atmosphere by causing a flow of air from the place of cooler to the place of warmer air, the warmer air rising and the cooler air flowing in to take its place, thus giving motion to the atmosphere and changing its density. We have no knowledge of just how far from the earth the air pressure ceases; but we do know that a few miles above the earth the quantity of air becomes very small.

Rarified Air is very perceptible, even without the aid of a barometer, to persons ascending rapidly into high elevations, such as up a mountain or in a balloon; some are subjected to mountain sickness, headache, difficult breathing; occasionally the walls of blood vessels burst and there is a flow of blood from the nose and ears. Relief, however, comes on a return to lower elevations and an increase of atmospheric pressure.

There is a decrease of temperature with an in-

crease of altitude and the air becomes rarer more rapidly with progress of ascent. Thus at a height of three and one-half miles the air is only one-half as dense as at the sea-level and at ten miles only one-eighth as dense, and the proportion of decrease of density is much greater above the latter height.

PRESSURE AND ALTITUDE.—The following table gives the air pressure according to elevation of every one-hundred feet up to one thousand, in the nearest round numbers.

TABLE OF ELEVATIONS FOR GENERAL PURPOSES.

Altitude Above Sea-Level.		Barometer Reading.	
FEET	0	INCHES	30.00
"	100	"	29.90
"	200	"	29.80
"	300	"	29.70
"	400	"	29.60
"	500	"	29.50
"	1,000	"	29.00
"	2,000	"	28.00
"	3,000	"	27.00
"	4,000	"	26.00
"	5,000	"	25.00
"	6,000	"	24.00
"	7,000	"	23.00
"	8,000	"	22.00
"	9,000	"	21.00
"	10,000	"	20.00

RANGE OF BAROMETRIC PRESSURE AT SEA-LEVEL.—In the United States the average pressure at sea-level is 30.00 inches. The general range at

sea-level is between 29.00 and 31.00 inches; occasionally it reaches as high as 31.20 inches; the lowest ever recorded at New York City was 29.83 inches on January 9, 1886.

CHAPTER IV

TEMPERATURE

THE thermometric changes which take place over all parts of the earth's surface depend upon the movement of the sun and its position about the horizon. While the sun is south of the equator, winter prevails in the northern hemisphere, and summer in the southern hemisphere, and *vice versa.* The sun crosses the equator coming north about March 21st, which is called the vernal equinox, at which time the duration of night and day is equal, each being twelve hours long. As the sun moves northward from the equator the period of daylight becomes longer and longer in all places of the northern hemisphere, until June 21st, when the longest day of the year is reached; after which the sun moves southward and the duration of daylight becomes less and less. The sun crosses the equator passing south about September 22d, which is called the autumnal equinox. The shortest day of the year occurs about December 22d. The difference in time

between the longest and the shortest day is about three hours.

Angle of the Sun.—In the tropical regions the sun's rays strike the earth vertically, which causes that part of the earth to receive the greatest amount of heat. Between the tropics and the polar circles the sun's rays strike the earth at an angle and glance off, which results in the middle latitudes having the most equable temperature. Within the polar circles the angle of the sun's rays is greatest, hence they exert but little power and the cold, except for a few weeks, is excessive.

How the Atmosphere is Heated.—The atmosphere is heated in two ways:—first, by absorbing from the rays of the sun about one-half of its heat; second, by radiation of heat from the earth. The temperature of the lower air depends primarily upon the amount of heat which is received at and radiated from the earth's surface, although there is an interchange of heat between the upper and lower layers of air. Air at the surface of the earth is also heated by contact with the earth and as heating decreases its density it rises and mingles with the cooler air of higher elevations.

Warmest Part of the Day.—The warmest part of the day occurs when the heat received from

the sun at the surface of the earth is just equal to the amount being radiated from the earth.

Radiation takes place soon after the maximum heat of the day, cooling both the air and the earth; it is more rapid on a clear than on a cloudy night; in fact, little or no radiation takes place when the sky is overcast with clouds.

Vegetation and plant life radiate heat very quickly, which accounts for the cool nights in the country. In the cities the nights are warmer than in the country because the enormous quantity of material used in the buildings and the pavements, being good conductors and poor radiators, retain the heat until long after nightfall.

Heat of the Day.—When the day is cloudless and the sun is in the zenith, the earth will receive its greatest proportion of heat; but when the sun is just above the horizon, the rays of the sun are nearly all absorbed by the atmosphere.

The Atmosphere a Shield.—The atmosphere serves as a shield in preventing a rapid radiation of the earth's heat into space, because the amount of aqueous vapor visibly suspended in the air as mist or cloud serves to prevent any rapid or extensive radiation of heat from the earth; the invisible particles of vapor also act as a shield for the reason

that vapors and gases are bad conductors of heat. This is evident on very cloudy or foggy days, when the temperature remains quite uniform owing to diminished radiation.

Were it not for this fact, it is calculated that the temperature at the earth's surface would fall to about 325 degrees below zero.

Daily Range of Temperature.—The difference between the highest and lowest temperature of the day varies considerably at different places and at any particular place at different times of the year. It is least near the seacoast and on islands situated some distance from the coast, and where there is excessive cloudiness. It is greatest over dry regions and where there is excessive sunshine. It is as a general rule greater in summer than in winter, the exceptions being due to local causes. In the United States, the daily range, west of the Mississippi River to the Rocky Mountains, varies from 20 to 35 degrees; east of that river to the Atlantic coast it varies from 12 to 20 degrees.

Daily Mean Temperature is the average of the highest and lowest temperatures for the day for any place. The difference between the highest and lowest temperatures at some places is very great.

To obtain the exact highest and lowest tempera-

tures for the day, the maximum and minimum thermometers are used, as these extremes may occur at almost any hour of the day or night.

The most accurate average of the day's temperature is obtained from hourly readings, but the labor incurred is so great that the self-recording thermometer is now employed for this purpose.

The fluctuations of the temperature are so great and frequently so rapid, that the average temperature of a day is not easily obtained. On some days the readings of instruments at intervals of fifteen minutes would not give a true mean.

To obtain the average of the highest and the lowest temperature for a day, add the readings and divide by their number; to obtain the result for hourly readings add all together and divide by the number of readings used.

The monthly average is obtained by adding the daily means and dividing by the number of days in the month.

The annual average is obtained by adding the monthly means and dividing by the number of months.

To determine the loss or gain of heat or cold take the average daily reading for any place desired for a number of years, and the excess or de-

ficiency of any single day's average, in comparison with that obtained for many years for the same day, will be the loss or gain for that day.

This method may be carried on throughout months or years to find the seasonal or annual change for any place.

The pronounced feature of continental temperatures is the great difference between the extremes of heat and cold. The greatest of these occur in the interior of continents, where radiation is most rapid, due to the comparatively small amount of aqueous vapor in the air.

On the other hand, we find the more even temperatures near the seacoast or islands.

The extremes of temperature, that is, the difference between the highest and the lowest, is called the *range.* In considering the climate of a place we must know the daily, monthly and annual range.

THE GREATEST RANGE OF TEMPERATURE recorded in the United States is from 64 degrees below zero, in winter in North Dakota, to 122 above zero, in summer in Death Valley, California, a difference of 186 degrees.

LOWEST AND HIGHEST TEMPERATURES EVER RECORDED.—The lowest temperature ever recorded on the earth was at Werchsjansk, in central Siberia,

January 15, 1855, when the thermometer touched 90.4 degrees below zero; the highest ever recorded was 127.4 degrees above zero, in Algeria, northern Africa, July 17, 1879, a range of 217.8 degrees.

Annual Range of Temperature.—The annual range in Montana is from 150 to 170 degrees. At New York City it is less than 100 degrees; the extreme range is 106 degrees. The smallest absolute range in the United States is on the Pacific Coast; the least is 60 degrees at San Francisco.

Except along the immediate border of a small part of the Pacific, South Atlantic and Gulf coasts, the absolute range of temperature everywhere in the United States exceeds 100 degrees, the range increasing everywhere from the coast line into the interior.

Ranges of temperature between 120 and 140 degrees prevail in the Ohio, the upper Mississippi and the Missouri valleys and the northern half of the Rocky Mountain section, and those exceeding 140 degrees are found in the Dakotas and Montana.

The greatest ranges for any section of the country are found in the latter states, being in the neighborhood of 170 degrees.

It is readily observed that the human race can stand any degree of temperature to which it is sub-

jected and in almost every part of the country, live throughout the year regardless of the great range of heat and cold.

The most trying and probably the most vital feature is the daily range. It is a well-established fact that a sudden and extreme range of temperature results more seriously to animal and vegetable life than even a greater range over a more extended space of time. Over all the country from the Missouri valley eastward, the mean daily range is from 12 to 20 degrees and from the Missouri valley westward, except along the Pacific coast line it is from 20 to 35 degrees.

The highest daily ranges occur generally in summer from May to July, except along the South Atlantic and Gulf coasts, where they occur in the winter months.

The most extreme and sudden changes occur in the Dakatos, Minnesota and Montana, due principally to intense cold waves moving down from British Territory which spread southward as far as Texas. In these states a fall of from 50 to 60 degrees sometimes occurs within a few hours; the greatest fall on record occurred at Abilene, Tex., December 27, 1886, when the temperature dropped 63 degrees in 16 hours.

The greatest rise on record occurred at Florence, Arizona, on June 22, 1881, 65 degrees, 50 degrees of which occurred in 8 hours.

It must be remembered that on account of the dry air of the localities where these remarkable changes happen, the intensity of the change causes less suffering to animal life than half of that change would cause in a section of country where the air contained from twenty to twenty-five per cent. more moisture.

Minimum Temperatures.—Zero temperatures occur over all parts of the United States, except on the coast of the Atlantic states south of Maryland, the states bordering the Gulf of Mexico, California and a strip of the coast of Oregon. The zero line starts on the Atlantic coast over Delaware Bay, runs thence southwesterly across the southeastern point of Virginia continuing to a few miles south of Charlotte, N. C., thence cutting more westerly through the centre of Georgia to the northwesterly intersection of the boundary line of northwestern Louisiana and southwestern Arkansas, thence west across the centre of Texas, turning to the northwest at the western boundary line and passing almost diagonally through Arizona, touching the western boundary line of Nevada, then running

almost to the coast line of Oregon where it inclines more to the northeast over a portion of Washington.

FREEZING TEMPERATURES.—Freezing temperatures in winter occasionally cover the entire area of the United States, except the southern part of the peninsula of Florida.

The temperature occasionally touches as low as 20 degrees in northern Florida and to within 10 degrees of zero in South Carolina, central Alabama, southern Mississippi, northern Louisiana and almost to the coast of Texas.

Temperatures touching 10 to 20 degrees below zero occasionally occur on the coast of New England, northern New York, Pennsylvania, Ohio, Indiana, Missouri, southern Kansas, northern Texas and to central New Mexico.

In the districts bordering the lake regions it touches from 20 to 30 degrees below zero and in the northwest from 30 to 60 below.

On the California coast it occasionally touches the freezing point.

MAXIMUM TEMPERATURES.—The highest temperatures that occur are called the maximum. In nearly every state in the union temperatures of 100 degrees have been recorded, except in Vermont and

Maine, the greater part of Utah and on the border of the Pacific coast north of San Francisco and on the coast of Texas; also over a strip of land in the mountain system extending from Vermont to Georgia.

Extreme temperatures as a rule last but a few days at a time and occur over but a part of the country at the same time; usually lasting longer and covering the largest section of country to the west of the Ohio Valley in the central-western states. Extreme heat does not prevail at elevated places; at Mount Washington the highest record is 74 degrees and at Pike's Peak 64 degrees.

Decrease of Temperature with Altitude. —The decrease of temperature with altitude is not uniform at all places, and changes with the season of the year; it averages about 1 degree for every 330 feet above sea-level and the change is more rapid in summer than in winter.

In winter in clear weather and especially at night it is colder in the valleys than on the hilltops and in summer during the day it is warmer in the valleys.

After a cooling of the general atmosphere by the passing of a cold wave, the cold air settles in the valleys and is retained long after the air of the

open country has lost all effect of the cold wave; likewise in summer the heat in the valleys lasts longer, because the general circulation of the upper air which changes the temperature of the hilltops fails to disturb the air of the valleys.

TEMPERATURE OF THE OCEAN.—Fresh water freezes at a temperature of 32 degrees and ocean salt water at a temperature of 27.5 degrees. The average temperature is about 50 degrees; the maximum temperature along the Atlantic coast varies from 30 degrees in February to 70 degrees in August.

Water is slow to absorb heat and is likewise slow in giving it up, which makes the extremes of heat and cold about one month later than the extremes of the month of air temperatures.

Shallow water is usually several degrees higher than deep water in summer and similarly colder in winter. Ice never forms to a greater thickness than six feet; a greater thickness is caused by the breaking and piling up of ice.

In flowing streams and rivers the constant movement of the water prevents freezing until the entire body is cooled to 32 degrees.

In still water as the surface is cooled it sinks and gives place to the warmer water which rises and is

in turn cooled until the whole mass is of the same temperature. Ice frequently forms on the bottom of lakes and streams around stones or other substances and when the weight of the ice is greater than the substance on which it forms it rises to the surface, carrying the stone or other object with it. This is called anchor ice.

Temperature of the Earth.—The range of temperature of the earth diminishes very rapidly with the depth below the surface. In the tropics the change ceases at a depth of one foot; in the middle latitudes it ceases at a depth of three feet; the depth increases with the distance into northern latitudes.

CHAPTER V

WINDS

WINDS.—From childhood we have heard—"The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh and whither it goeth."

Science, however, teaches that the winds are governed by well-defined laws.

We may ask, What is wind? The answer would be—air in motion. When the air is at rest and the atmosphere calm, we feel the loss of the pressure it would exert if in motion. Wind is invisible and we only know of its movement by its force and pressure and by the observance of particles of dust carried in the air and the pressure exerted on larger objects which are visible to the eye.

There would be no motion to the air were it not for the unequal distribution of heat from the sun over the earth's surface, which causes a change in the density of air. The more heated air rises and causes a flow of cooler and more dense air from place to place, thus seeking to establish an equilib-

rium of the atmosphere, which fortunately is never accomplished.

Circulation of Wind.—There is a constant flow of air from the equator towards the poles through the upper atmosphere and a return current through the lower air strata from the poles towards the equator, due to the unequal temperature of those regions.

The general circulation of air is governed by the rotation of the earth, which deflects air currents to the right in the northern hemisphere and to the left in the southern hemisphere. The movement of air currents in the middle latitudes is from west to east.

Direction of the Wind.—The direction of the wind is designated by the point from which it blows; that is, if a wind is blowing from the east, it is an east wind; if it blows from a point between north and west, it is a northwest wind, etc.

For general use, the compass is divided into eight principal points, as follows: North, northeast, east, southeast, south, southwest, west and northwest.

Trade-Winds.—These winds are the most permanent of the general wind system. The northeast trade-winds prevail over land and sea from latitude 7° to 29° north of the equator and

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

the southwest trade-winds prevail from latitude 3° to 20° south of the equator all the year round. They have not very great velocities, but their regularity of motion and velocity, although quite constant, varies somewhat over the ocean and the modification is still greater over the land.

The entire system of trade-winds shifts from south to a few degrees farther north in summer than in winter; they follow the sun northward and southward, but lag about one month behind in their movement.

Belt of Calms.—Between the northeast and southeast trade-winds there is a "belt of calms," or "Daldrums," as they are frequently called, which vary in width from 150 to 500 miles. They extend from the equator to 11° north latitude on the Atlantic, and from 3° to 10° north latitude on the Pacific ocean. The region covered by the belt of calms is where the two systems of trade-winds meet.

Sailing vessels experience great difficulty in passing through this belt and are frequently delayed many weeks.

Anti-Trade Winds.—These winds prevail in the middle latitudes from about latitude 30° to 50° on both sides of the equator. They are the higher

air currents and in the northern hemisphere they blow from the southwest; in the southern hemisphere they blow from the northwest.

Surface Winds.—The prevailing direction of the surface winds over the greater part of the United States is from southwest to northwest, and they blow practically in harmony with the anti-trade-winds (the upper currents). The general trend of the surface wind is to blow to a point slightly to the north of east.

Monsoons.—The monsoon winds are due to seasonal changes of temperature which causes an unequal heating of land and water; the continents are warmed up more in the summer than the ocean and cool off more in winter, which gives rise to a flow of wind during the warmer months from the ocean towards the interior of continents, and during the winter months from the land towards the ocean. The action is similar to the daily land and sea breezes.

Ocean Breeze.—There is a daily variation to the wind direction at the sea-coast, due to the difference of daily heating of land and water. During the daytime the wind blows from the sea to the land. At night the wind blows from the land to the sea. This is caused by the land heatin

up more rapidly than the sea during the day and radiating the heat quicker at night, the wind always flowing from the cooler to the warmer section. The intensity of the breeze depends upon the difference of temperature of the land and sea and the rapidity of radiation. A great difference in temperature creates strong winds and the same takes place with rapid radiation. The breeze lasts until the air over these surfaces is equalized.

If it diminishes during the night, it is generally revived with the passing of the sun above the horizon in the morning.

FOHN-WIND.—This applies to hot, dry winds of mountainous regions.

These hot winds are prevalent in the Rocky Mountain regions and are there called "Chinook" winds. They prevail from British Territory southward over Montana, Wyoming and Colorado, also in the interior mountain districts of Idaho and Washington, and are caused as follows: the air in passing over a mountain range leaves all the moisture it contains (condensed by the coolness of elevation), deposited on the west side of the mountains; the condensation liberates the latent heat, which again becomes sensible heat and raises the temperature of the air. This warm, dry air flows

over the eastern range of the mountains, modifying the winter temperature and quickly disposing of the ice and snow on the approach of spring, but is very destructive to vegetation in the warmer months. Its intensity diminishes with the distance from the mountains. The "Chinook" may last from a few hours to several days. It is in winter a soft, balmy wind, varying in force from a gentle breeze to a heavy gale. On the arrival of this wind which comes from the west, the temperature frequently rises 40 or 50 degrees in a few hours.

Hot Winds of Texas.—The hot winds which prevail in Texas usually blow from April to September, the most destructive period occurring from the middle of May to the middle of July. During this time the earth becomes baked and vegetation is generally destroyed. These winds are coincident with the formation or movement of low atmospheric storms in the Missouri valley. The hot winds at such times blow from a westerly point, turning to cooler northerly winds with the disappearance of the atmospheric depression.

"Northers."—The cold northerly winds of winter, which spread from Montana to the Gulf of Mexico and in a few hours lower the temperature from 30 to 50 degrees, are called "Northers" in

the Southwest. This term is more closely associated with Texas than with any of the other southwestern states. These cold winds are usually dry, but are occasionally attended by some snow or sleet.

Blizzards.—These same cold winds in the Northwest are called "Blizzards."

The term "Blizzard" does not apply unless the winds are accompanied by fine cutting ice particles. In many of these "Blizzards" the wind attains a velocity of 40 or 50 miles an hour, which may last several hours or a whole day, with the temperature from 20 to 30 degrees below zero.

Hot Winds of California.—The hot winds of California are known as the "Desert winds"; they are easterly winds and blow from the interior of southern California towards the Pacific Ocean.

The Prevailing Winds East of the Mississippi.—The prevailing winds over the eastern half of the United States blow from the southwest to northeast. During the summer months, however, on the Middle Atlantic and New England coasts they blow from a more southerly to a northerly point. In the Gulf States the prevailing direction is from the south to southeast shifting to more northerly over Texas during the winter.

WIND VELOCITIES.—If the velocity of wind in miles per hour were equally distributed over the entire United States, it would average about ten miles per hour for all places.

On the Middle Atlantic and New England coasts the average is 13 miles an hour; on the South Atlantic and Gulf coasts, 11 miles an hour; on the Pacific coast, 6 miles an hour; in the Central States, about 7 miles an hour, except in the vicinity of the Great Lakes, where it averages about 11 miles an hour.

HOURS OF HIGHEST DAILY WIND VELOCITY.—The daily wind velocity at nearly all places in the United States is least from 1 A. M. to 7 A. M. and greatest from 10 A. M. to 5 P. M.; it then decreases to about the same velocity as in the early morning hours. As a general rule the wind velocities are higher at all hours during the winter than during the summer.

MONTHS OF GREATEST AND LEAST WIND VELOCITIES.—The highest wind velocities in the eastern half of the United States usually occur in March, and in the western half in April. The month of least wind is August at nearly all places.

PLACES OF HIGHEST WIND VELOCITIES.—The highest wind velocities recorded have been from 50

to 138 miles an hour on the Atlantic coast, and from 50 to 70 miles an hour inland. On the Pacific coast they increase from 40 miles an hour in southern California to 90 miles an hour at Oregon and Washington. At elevated places and in individual storms the wind velocities have greatly exceeded the general rates given for districts.

The highest recorded velocity on the Atlantic coast was 138 miles an hour at Cape Lookout, which occurred during the great hurricane of August 17, 1879. At Mount Washington, it is no unusual occurrence to have a wind velocity of 100 miles an hour. The highest wind velocity ever recorded, was 186 miles an hour, at this place, on January 11, 1878.

There is no reason to doubt that wind velocities of such severe storms as the Louisville and St. Louis tornadoes exceed three hundred and probably reach five hundred or more miles an hour.

CHAPTER VI

EVAPORATION AND HUMIDITY

MOISTURE.—Moisture is one of the most important elements of the atmosphere; its relation to health and its bearing on the formation and progress of storms are not fully known and, regardless of these facts, its measurement is less accurately determined than that of any other atmospheric element.

GASES, VAPORS AND LIQUIDS.—In speaking of moisture in the air, we may use the words, gas or vapor, which have no essential difference of meaning. Liquids or solids are changed into vapors or gases by evaporation and are invisible, except when condensed and form fog or cloud or precipitated in solid form as rain, snow, sleet or hail.

The word vapor applies more especially to visible forms of moisture and the word gas to the invisible.

Some liquids such as ether, alcohol, etc., are transformed into the gaseous state very rapidly; water however possesses properties which causes

somewhat slower evaporation; but it evaporates very readily.

Cause of Evaporation.—The rapidity of evaporation depends upon the temperature; if the temperature is high and the atmosphere comparatively dry, evaporation is greatly accelerated. This is fully demonstrated by the use of a fire to hasten evaporation.

The heat utilized in the process of evaporation becomes latent, that is, its heating qualities are lost, so that, in changing a liquid or solid form of water into the gaseous condition of aqueous vapor the surrounding atmosphere is cooled according to the amount and rapidity of the evaporation.

High winds and high temperature facilitate rapid evaporation.

The effect of evaporation on perspiring humanity is shown by a draught of air or the use of a fan; the moisture is soon dried and the coolness resulting therefrom, due to evaporation, brings relief.

Evaporation at All Times.—Evaporation goes on at all times and under all atmospheric conditions in proportion to the temperature and the amount of moisture present. A cubic foot of air contains aqueous vapor in quantities varying with the temperature. When it has all the moisture it

can contain it is said to be saturated. If the temperature remained stationary, the progress of evaporation would cause condensation; or should the temperature become lower, condensation would also take place; but should the temperature become higher, the amount of vapor would diminish.

Amount of Evaporation.—The greatest evaporation takes place in the tropics and is least in the Arctic regions. The normal condition prevails in the middle latitudes. It is greatest during the warmest part of the day and least at night.

By practical demonstration water can be easily frozen by the cold resulting from its own evaporation.

The amount of water evaporated in the shade during the year varies widely in different places throughout the United States. On the New England coast it is about 39 inches; on the Middle Atlantic coast, about 43 inches; in the Ohio valley, about 40 inches; in the southern states it varies from 50 to 70 inches, and in the extreme western and southwestern states it varies from 70 to 100 inches; the greatest amount evaporated is in New Mexico, Arizona and California.

When exposed to the sun and wind the amount of evaporation is still greater.

Evaporation may be measured by exposing a pan or bucket containing water to the open air, using an ordinary measuring rule.

HUMIDITY.—The term humidity we understand to mean the moisture in the air and its presence determined by instruments as explained in Chapter II.

It is this element of the air which causes the greatest amount of suffering in summer; more especially along the seacoast than inland.

Humidity involves two elements:—First—The amount of vapor present; second, the amount which would thoroughly saturate the air at the actual temperature. It is upon the ratio of these elements that our sensations of dryness and moisture depend.

ABSOLUTE HUMIDITY.—Absolute humidity we understand to be the full amount of moisture in the air, regardless of the temperature. In its watery condition it is measured in grains per cubic foot. In its gaseous condition it is measured by the pressure or tension exerted on the barometer.

RELATIVE HUMIDITY.—Relative humidity we understand to be the amount of moisture, in percentage, relative to the actual temperature. The moisture in the air is constantly undergoing a change, either by a rise or fall of temperature or

by condensation of a portion of its supply in precipitation of some form.

Air is said to be dry when the relative humidity is below the average for the place.

Capacity of the Atmosphere.—The atmosphere has a capacity for holding 100 per cent. of moisture, at which point it is said to be thoroughly saturated and condensation must take place in the shape of rain, snow, etc., according to the season of the year, to make place for the moisture that is being taken up by evaporation. It is not necessary for the atmosphere to contain 100 per cent. of moisture before condensation takes place; rain or snow may fall when the humidity registers 40 per cent. or even less, and frequently occurs when the percentage is between 60 and 80; but it must necessarily take place when it reaches 100 per cent.

Capacity Increases with Temperature.—When the heat of the day is increasing, the capacity of the atmosphere for taking up moisture and holding it becomes greater with every additional degree of temperature; but when the maximum heat for the day has been reached and there is from 60 to 80 per cent. of moisture in the air, there is still space for more moisture. Now the turning-point comes when the temperature recedes from its highest

point; with each degree of decrease, the atmosphere is contracting and the capacity for holding all the moisture it has taken up during the heating and expanding process becomes less and less while the percentage of humidity becomes greater and greater. For instance, if the temperature reached 70 degrees and the humidity stood, say, at 70 per cent. when the temperature dropped to 50 degrees, the humidity would reach the point of saturation or 100 per cent., and condensation in some form would take place.

Greatest Capacity.—The atmosphere has its greatest capacity for evaporating and holding moisture on clear days, which is several times as great as on cloudy or rainy days.

The humidity generally decreases on clear days and increases on cloudy days regardless of the difference in its capacity.

The percentage of humidity is supposed to increase up to the lower cloud level and rapidly decrease above that point; it is believed that very little moisture is carried into the higher strata of air, for the reason that rainfalls are mostly from the lower clouds.

Places of Greatest and Least Humidity.—Humidity is usually high near the seacoast, bodies

of warm water, large fields of snow, swamps or meadows. It is lowest in the interior and with an increase of distance from bodies of water. It is especially low in the plains and plateau regions of the Rocky Mountains.

Humidity usually decreases after condensation takes place.

Humidity increases on the Atlantic coast when the wind is from an easterly direction and diminishes with the wind from a westerly direction. The reverse occurs on the Pacific coast. In the Southern states the humidity is highest with a southerly wind and lowest with a northerly wind.

Humidity—Highest and Lowest.—Relative humidity is highest during the winter months and lowest during the summer months; it is likewise higher during the night than during the day.

Transparency of Dry Air.—Dry air lends a peculiar transparency to the atmosphere. In the central and southern Rocky Mountain districts, objects at a distance of from 40 to 70 miles away may be seen with the naked eye and appear but a few miles off.

CHAPTER VII

CONDENSATION AND PRECIPITATION

DEW-POINT.—The amount of aqueous vapor which the air can hold depends upon the temperature. When moist air is cooled its relative humidity increases; if it is cooled far enough it will reach saturation point and condensation will take place. The dew-point is that temperature at which invisible moisture is condensed into water. This may be easily demonstrated by placing ice in a pitcher in a warm room and noting the temperature at which the dew appears on the outside of the pitcher; the warm, moist air comes in contact with a cooler surface and the moisture is thus condensed.

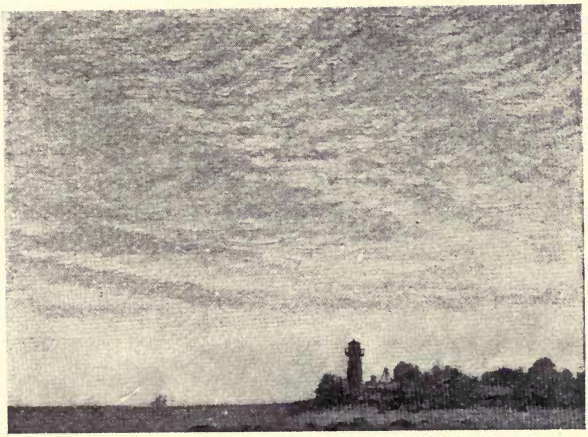
CONDENSATION.—The condensation taking place in the atmosphere is attributed to warm, moist air arising and mingling with the colder air at higher elevations, the ascending air being cooled 1 degree for a distance of about 330 feet; the rate of decrease varies for different months of the year and for dif-

ferent hours of the day and is greater inland than near the ocean.

Fog.—When condensation of moisture takes place in the air it is evidenced by the formation of fog or cloud; if it takes place to a greater extent, it is shown in the precipitation in the form of rain, snow, sleet or hail, which reaches the earth's surface.

The minute drops of visible vapor which form fog and cloud were once supposed to be hollow spheres; but science now claims that each drop is a solid body of moisture formed around some particle of dust in the atmosphere and supported by the upward tendency of air currents and the resistance of air to the falling of minute spherical particles. When the weight of the drops increases and they become heavy enough to overcome these forces they fall to the earth's surface; if the ascending body of air-currents ceased to support them, they would likewise fall of their own weight. These particles of vapor in passing from a higher to a lower elevation may be absorbed by warmer air and again pass into a state of invisible vapor.

Visible moisture suspended in the air is called "Cloud"; when resting on the earth it is called "Fog."



No. 1. Cirrus

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

How Fog is Caused.—Fog is caused by a contrast of temperature between the air and the land or water; by warm, moist winds blowing over a cold body of water or cold, damp ground or by cold winds blowing over a warm body of water or warm, moist ground. If the radiation of heat from the earth is excessive, the air resting near the surface becomes rapidly cooled and condensation takes place, forming fog or mist, and increases from the ground upward. Fog forming under the above conditions lasts until the temperature conditions are equalized and usually dissipates from the top downward.

Frequency of Fog.—Fog occurs with greatest frequency over or near large bodies of water, where great and sudden changes of temperature take place.

Fog forms more frequently at night and disappears shortly after sunrise. Fog prevails more frequently in the United States, along the northern part of the Middle Atlantic and New England Coasts and thence increases northward to the Banks of Newfoundland.

Mr. E. B. Garriott, of the Weather Bureau, who made a careful study of the dense fogs of the North Atlantic, states that they are caused by the

warm, moist currents of air from the gulf stream, three hundred miles to the east, being carried over the cold water of the "Banks" by the southeasterly winds blowing into low pressure areas advancing from the west.

The temperature over the North Atlantic, in July, is 45 degrees, while that of the gulf stream is 78 degrees.

Fogs are noted along the North Pacific coast during the winter months; their advent marks the beginning of the rainy season in that section.

Fogs are rarely more than 1,500 feet in thickness above the ground and occasionally they do not extend more than 50 feet above the ground; the average thickness is about 150 feet.

Dry Fog.—During a period of clear weather the air becomes filled with very minute dust particles forming a sort of haze, which obscures the sun and occasionally lasts for days and weeks.

Indian Summer.—A dry, mild, hazy condition usually occurs in November or the early part of December and at such times is called "Indian Summer." The atmosphere is cleared with the first fall of rain thereafter.

Clouds

Clouds.—The clouds furnish the most satisfactory indication of the changes which are constantly taking place in the upper air. Their formation, kind, position, amount and direction of movement, are most valuable features to consider in determining weather changes.

Cloud Formation.—Clouds form when the ascending and expanding currents of warm air reach an elevation where they are cooled below the temperature of the dew-point. When the air is uniformly heated to a great height there may be few if any clouds, even though there be considerable vapor.

The distance at which cloud formation takes place depends upon the difference in temperature of the ascending warm currents and that of the air through which they pass.

Classification of Clouds.—Owing to the numerous forms of clouds, their classification has been subjected to many changes. For scientific purposes they have been divided into ten different types, but for general and practical use the seven principal forms are all that are necessary and are probably all that the ordinary observer can decipher.

They are divided into two general classes, upper and lower, according to their elevation, and are as follows :—

Upper	Lower
1. Cirrus.	4. Strato-cumulus.
2. Cirro-stratus.	5. Nimbus.
3. Cirro-cumulus.	6. Cumulus.
	7. Stratus.

Cirrus Clouds.—The cirri are delicate fleecy wisps of vapor, presenting a feathery whiteness against a blue sky, their beautiful shapes occasionally arranged in bands forming what is known as the "mackerel sky" or "mare's tail." They are the highest of all clouds; the lowest elevation at which they are found is about five miles and their usual height is from six to eight miles.

Cirro-Stratus.—The cirro-stratus is a fine, fibrous cloud composed of ice particles, forming a whitish vail of haze, which produces halos or rings around the sun and moon; they usually precede rain or snow. Their elevation varies from three to about six miles.

Cirro-Cumulus.—They are small balls or bunches of cloud partly connected by broken threads, resembling balls of cotton. Although

each ball is only partly connected with its neighbor there is or no shading of light. These fleecy clouds are of a grayish-white and have an attitude varying from three and one-half to five miles.

STRATO-CUMULUS.—These clouds belong to the lower air strata; they form at an elevation of from three-quarters to one mile and a half above the earth. They may properly be called a winter cloud, as they are frequent in cold, dry weather. They have a flat base and a rather broken rounded top and give the sky near the horizon a dark threatening appearance.

NIMBUS.—This is an alternately light and dense mass of broken cloud, with ragged edges and without any formation; it is simply a confused mass, drifting with the lower winds and from which rain or snow falls. Its elevation is from three-quarters to about one mile and a half.

CUMULUS.—The cumulus clouds present a fine appearance in the sky. They form in huge, white masses like mountains of snow, extending from a horizontal base to a fine rounded or dome-shaped top. They are principally summer clouds and are most frequent in the afternoon and evening, when they extend well up towards the zenith; the illumination of these clouds at sunset is very pretty; they

are occasionally called "thunder-heads." They form mostly over the land in the lower air strata and are less numerous after nightfall.

STRATUS.—The name indicates the character. They are the lowest of all clouds and are observed close to the horizon in the shape of a streak of fog resting on the earth and extending in horizontal bands to a height of one or two thousand feet. They form principally after sunset and give a cold, gray, gloomy appearance to the sky.

CLOUD SHADOWS.—The shadows of clouds screen the earth from extreme heat in summer and in winter form a screen to prevent too great and rapid radiation of heat from the earth.

The diverging lines of light from the sun, so noticeable at sunrise and sunset, are caused by the shadow of the clouds near the horizon being projected on the sky while the sun is below the horizon. The appearance they produce is spoken of as "the sun drawing water."

AMOUNT OF CLOUDINESS.—A clear day is one in which no clouds appear. A fair day is one which is partly cloudy at least a part of the day, and a cloudy day is one in which the sky is cloudy the whole of the day.

The least cloudiness is about noon and the great-

No. 2. Cirro stratus

No. 3. Cirro-cumulus

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

est about sunrise and in the evening; then there is a decrease at night.

The average cloudiness varies greatly at different places and at different times.

In the states east of the Mississippi the average is about 50 per cent.; west of that river, it ranges from thirty to forty-five per cent. annually.

The average cloudiness over the United States is least in the month of August and greatest, as a general rule, in January.

The largest percentage of cloudiness east of the Mississippi is found on the southern shore of Lake Ontario from Buffalo to Oswego, it being 60 and 63 per cent. respectively .

The least percentage of cloudiness in the entire United States is found in southeastern California and the valley of the Colorado, being 19 per cent. in the former and 17 in the latter. In western Texas, New Mexico, Arizona and northern California, the average annual cloudiness is 25 per cent.

During the summer months in New Mexico, Arizona and southern California, the average cloudiness is less than 8 per cent.

At New York City the daily average number of hours of sunshine in July is 11, and in December 5.

APPROXIMATE HOURS OF POSSIBLE SUNSHINE.

From 25° to 49° North Latitude, inclusive.

(Use latitude nearest that of station, interpolating when necessary.)

Date.		25°	27°	29°	31°	33°	35°	37°	39°	41°	43°	45°	47°	49°
Jan.	1	10.6	10.5	10.3	10.2	10.0	9.9	9.7	9.5	9.3	9.1	8.8	8.6	8.3
	11	10.7	10.6	10.4	10.3	10.2	10.0	9.8	9.7	9.5	9.3	9.1	8.8	8.6
	21	10.8	10.7	10.6	10.5	10.4	10.2	10.1	9.9	9.7	9.6	9.4	9.2	8.9
Feb.	1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.2	10.1	10.0	9.8	9.6	9.4
	11	11.2	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10 4	10.3	10.1	10.0
	21	11.5	11.4	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.6	10.6
Mar.	1	11.7	11.6	11.6	11.5	11.5	11.4	11.4	11.4	11.3	11.2	11.2	11.1	11.0
	11	11.9	11.9	11.9	11.8	11.8	11.8	11.8	11.8	11.8	11.7	11.7	11.7	11.6
	21	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Apr.	1	12.4	12.4	12.5	12.5	12.6	12.6	12.6	12 6	12.7	12.7	12.8	12.8	12.9
	11	12.6	12.7	12.8	12.8	12.9	12.9	13.0	13.0	13.1	13.2	13.3	13.4	13.5
	21	12.9	13.0	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.1
May	1	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.9	14.0	14.1	14.3	14.4	14.6
	11	13.3	13.4	13.5	13.6	13.8	13.9	14.0	14.2	14.4	14.5	14.7	14.9	15.1
	21	13.5	13.6	13.7	13.9	14.0	14.2	14.3	14.5	14.7	14.9	15.1	15.3	15.6
June	1	13.6	13.7	13.9	14.0	14.2	14.4	14.6	14.7	14.9	15.2	15.4	15.7	15.9
	11	13.7	13.8	14.0	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.6	15.9	16.1
	21	13.7	13.9	14.0	14.1	14.3	14.5	14.7	14.9	15.1	15.4	15.6	15.9	16.2
July	1	13.7	13.8	14.0	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.6	15.8	16.1
	11	13.6	13.7	13.9	14.0	14.2	14.4	14.6	14.8	14.9	15.2	15.4	15.7	15.9
	21	13.5	13.6	13.7	13.9	14.0	14.2	14.4	14.5	14.7	14.9	15.1	15.4	15.6
Aug.	1	13.3	13.4	13.5	13.6	13.8	13.9	14.0	14.2	14.4	14.5	14.7	14.9	15.1
	11	13.1	13.2	13.3	13.4	13.5	13.6	13.8	13.8	14.0	14.2	14.3	14.5	14.6
	21	12.9	13.0	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	14.0	14.1
Sept.	1	12.6	12.7	12.8	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.4	13.4
	11	12.4	12.4	12.5	12.5	12.5	12.6	12.6	12.6	12.7	12.7	12.8	12.8	12.8
	21	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.3	12.3
Oct.	1	11.9	11.9	11.9	11.9	11.8	11.8	11.8	11.8	11.8	11.7	11.7	11.7	11.6
	11	11.7	11.6	11.6	11.6	11.5	11.5	11.4	11.4	11.3	11.3	11.2	11.1	11.1
	21	11.4	11.4	11.3	11.2	11.2	11.1	11.0	11.0	10.8	10.8	10.7	10.6	10.5
Nov.	1	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.0	9.9
	11	11.0	10.9	10.8	10.7	10.6	10.4	10.3	10.2	10.0	9.9	9.7	9.5	9.3
	21	10.8	10.7	10.6	10.5	10.3	10.2	10.0	9.9	9.7	9.5	9.3	9.1	8.9
Dec.	1	10.7	10.6	10.4	10.3	10.1	10.0	9.8	9.6	9.5	9.2	9.0	8.8	8.6
	11	10.6	10.5	10.3	10.2	10.0	9.8	9.6	9.5	9.3	9.1	8.8	8.6	8.3
	21	10.6	10.4	10.3	10.1	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.5	8.2

Rainfall.

Rain.—The cause of condensation sufficient to produce rain has been given more consideration than other atmospheric phenomena, and the theories of the most eminent scientists have, until recent years, differed widely. It will not be necessary to discuss the various theories; it is sufficient to say that the generally accepted theory is that rain is produced in greater or less quantities by warm, moist air ascending and becoming cooled by expansion or elevation. Precipitation begins when the temperature of the moist air is cooled below the dew-point and falls as rain or snow according to the season.

The occurrence and distribution of rainfall over the surface of the earth is very erratic. It is not thought that rain is produced to any extent by warm, moist air flowing horizontally to a place of cooler air or passing over a cooler surface; it will, however, result if the warmer winds are forced upward by the configuration of the land.

Heavy Rainfall.—Heavy rainfall occurs near the seacoast where there is a high average temperature and the prevailing wind is towards the land.

Least Rainfall.—The least rainfall occurs at places contiguous to the sea at the higher eleva-

tions, where the temperature average is low. There is also a deficiency of rainfall in the higher land elevations of the extreme west and southwest, caused by the westerly winds depositing their moisture on the western side of the Rocky Mountains.

Daily Rainfall.—The greatest frequency and greatest amount of rain falls at, or shortly after, the warmest part of the day, usually between 4 and 7 P. M. The reverse of these conditions occurs between 5 and 8 A. M. The amount of rain is about three times as great in the former as in the latter hours. These hours vary somewhat with the season, being a little later in summer than in winter.

Rainfall Increases with Elevation.—There is a marked increase of rainfall with elevation up to a height of 5,000 feet; above that height there is a decrease. The increase up to 2,000 feet is at the rate of two-thirds of an inch for every 100 feet.

The annual rainfall on Mount Washington averages about 83.5 inches, while at Boston it is 46.8 inches.

If all the vapor in the air should be condensed at the same moment of time, it would cover the entire earth to a depth of four inches.

One inch of rainfall over a square mile of surface exceeds one million cubic feet of water.

Distribution of Rainfall.—There is a great variation of rainfall over the different states of the Union. The annual average ranges from less than 8 inches in Arizona to over 100 inches on the coast of Washington.

The quantity of rainfall depends on the distance from the seacoast, the elevation, the direction of the prevailing winds, and the frequency of passage of storms; except on the Pacific coast, the rainfall is least in the southern section and increases quite steadily to the northern section. There is a marked contrast to this rule on the Atlantic coast; the rainfall is heaviest on the South Atlantic and decreases towards the North Atlantic section.

Annual Rainfall.—An annual rainfall exceeding 44 inches occurs on the Atlantic and Gulf coasts, diminishing westward and northward to Minnesota to 30 inches. In the states on the east slope of the Rocky mountains the rainfall is less than 20 inches and in southern California, southwestern Utah, southern Nevada and western Arizona, the fall is less than 8 inches annually.

On the Pacific coast there is a rainy and dry season; nearly all the rain falls during the winter

months and little or none during the summer months.

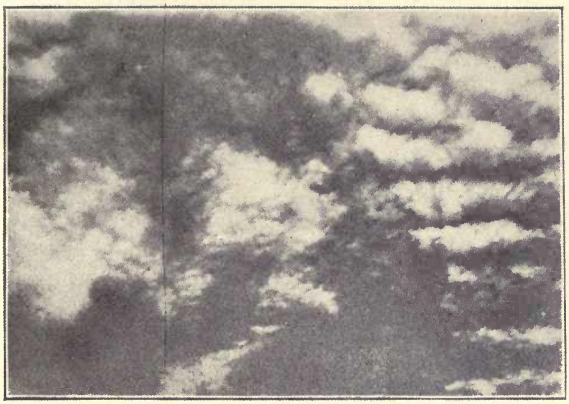
The heaviest rainfall in the United States occurs in the extreme northwest corner, at Cape Flattery.

At no place in the world is there such a uniformly and well-allotted amount of rainfall as in the middle districts of the United States from Iowa and Missouri east to the middle Atlantic coast; it ranges from 40 to 60 inches per annum.

Heavy rains exceeding 100 inches per annum have occasionally occurred at places along the middle Atlantic coast, but such heavy rains are not to be expected, and are caused generally by the passage of tropical storms, which greatly add to the annual allowance.

The United States is favored by the greater portion of its rainfall being moderate and although the distribution is not equable, each state receives about the same amount year after year. The periods of drought or excessive rain may increase or decrease and prevail at irregular seasons, still there is never a month where more or less rain does not fall at nearly all places.

The erratic feature of monthly rainfall is shown by the record for the month of September at New York City, in which the average fall is 3.53 inches.

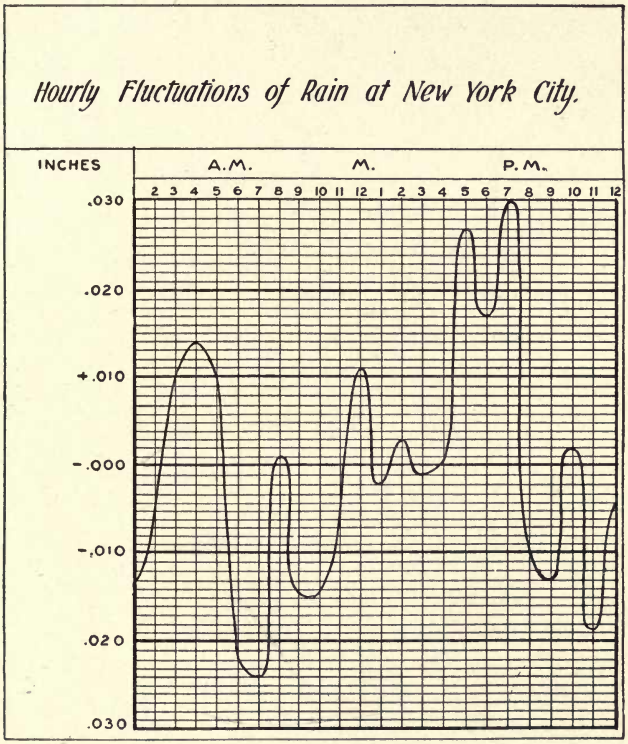


No. 4. Strato-cumulus

No. 5. Nimbus

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

There we find the highest and the lowest monthly rainfall on record for this place occurring with but one year of about average rainfall intervening; in



1882, 14.51 inches fell and in 1884 but 0.15 of an inch fell.

September in New York City and vicinity is

about the dryest period of the year, and from July 15th to August 15th the wettest period.

There is probably no part of the earth where rain does not fall occasionally. As far as known the smallest rainfall in the world occurs in southeastern California, southern Colorado, western Arizona and the Mohave Desert; in sections of these places the rainfall is less than three inches annually and in a few spots less than two inches.

The average monthly rainfall east of the Mississippi river varies from 2 to 4 inches, but there is occasionally considerable deviation.

Rainfall exceeding ten inches in a single month has frequently occurred in the gulf states, along the south Atlantic coast and on the north Pacific coast and occasionally it has exceeded twenty inches. An excessive rainfall of thirty-seven inches occurred at Alexandria, La., in June, 1886.

The average rainfall on a single day in the United States is .02 of an inch. This may seem insignificant, but it is sufficient to thoroughly wet the surface of the ground; more than half of the rainfalls do not exceed .05 of an inch; half an inch of rainfall is considered heavy; falls of one inch, however, are common; rainfalls of two inches or more per day occur occasionally.

NUMBER OF HEAVY RAINFALLS.—In the United States a record for twelve years gives the number of cases where the daily rainfall exceeded four inches, as 1,506, divided as follows: 4 to 5 inches, 805; 5 to 6 inches, 352; 6 to 7 inches, 163; 7 to 8 inches, 83; 8 to 9 inches, 35; 9 to 10 inches, 27; 10 to 11 inches, 20; 11 to 12 inches, 6; 12 to 13 inches, 5; 13 to 14 inches, 6; 14 to 15 inches, 2; 17 inches, 1 and 22 inches, 1.

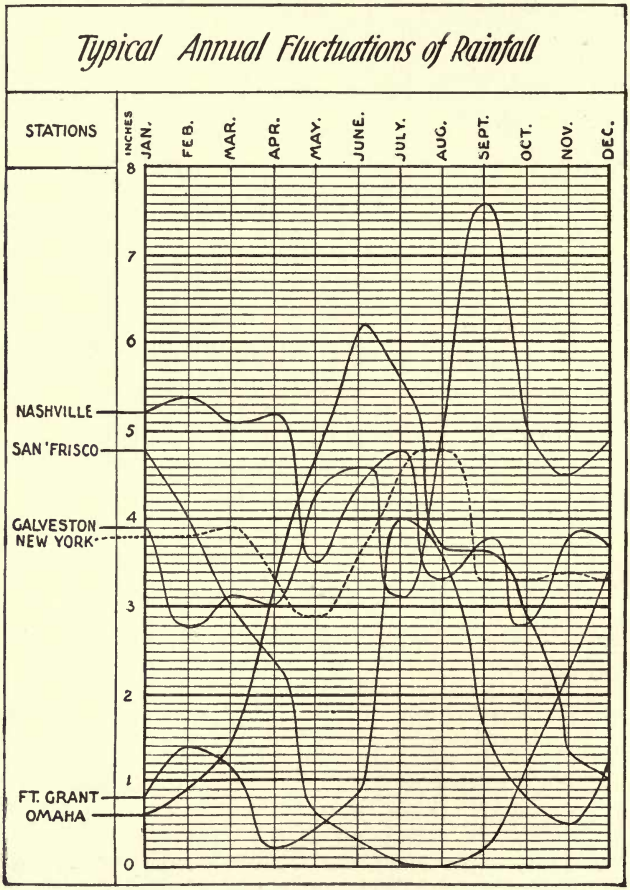
HOURS OF RAINFALL.—The average hours of continuous rain in the United States is as follows: Atlantic and Gulf states, 6 hours; Ohio and Tennessee valleys, lake regions and Mississippi valley, 5 hours; central Rocky Mountain and Plateau districts, 3 hours; Pacific coast, 6 hours.

RAINY DAYS.—The number of rainy days, that is, when the rainfall is .01 of an inch or more, ranges from 125 to 150 in the Atlantic and Gulf states; 90 to 120, in the central states and upper Mississippi valley; 150 to 170, in the lake regions; 70 to 90, in the Rocky Mountain Plateau region; 50 to 70, in Texas; 14 to 22, in southern California and Arizona, and from 66 at San Francisco to 170 at the north coast of Washington.

Near the seacoasts or great lakes the prevailing

direction of the wind occasions the period of dry and wet months.

CLOUD-BURSTS.—Cloud-bursts are sudden and



extremely heavy down-pours of rain, occurring over a very limited area and usually attendant upon the passing of a severe local storm. They have been known to occur over very dry sections of country and are in most cases very destructive, especially in hilly country, where the entire fall of water flows into the immediate valley.

Snow.

Snow-Fall.—When condensation of vapor takes place with a temperature of freezing (32 degrees) or lower, the precipitation will fall as snow. Snowflakes do not form in globules of water as does rain, but in minute ice crystals, assuming a great variety of hexagonal forms.

Snowflakes preserve their beautiful forms if the temperature of the air throughout is below freezing point. If the lower air should be above freezing, then the flakes lose their form readily and pass to the earth in watery form.

Snowflakes forming at very low temperatures become ice spicules, and are of small, angular shape. When they form with the temperature near the freezing point the flakes are large and consist of beautifully formed crystals.

Snow has frequently occurred with the temperature near the earth as high as 40° and rain has been recorded with a temperature as low as 26°. In the former case, it was due to colder air currents, where the temperature was below freezing, running close to the earth's surface, and the snow not having time to melt before reaching the earth's surface; in the latter case, the upper currents, where the rain was formed, were warmer than those at the earth's surface and above freezing point.

Districts of Snow.—Snow falls over all parts of the United States, except the extreme southern end of the peninsula of Florida. On the Pacific coast south of San Francisco, it seldom falls. Snow never remains on the ground in the Southern States for any material length of time and in the Gulf States the fall rarely exceeds one or two inches.

Depth of Snow.—The average depth of snowfall in the United States varies considerably from year to year; it is heaviest in Maine and decreases to the westward to the Rocky Mountains. As near as can be measured, the depth in Maine averages 8 feet; New York, 7 feet; Michigan, 5 feet; Iowa, 4 feet; Minnesota, 3 feet; North Dakota, South Dakota, Montana, Wyoming and

Nebraska, 2 feet. On the Sierra Nevada Mountains the depth in a year ranges from 10 to 30 feet. In all sections the heaviest snow falls from December 1st to March 1st.

In northern New York and New England from 8 to 12 heavy snow-storms occur during the winter. In the vicinity of the lower lakes local snow flurries are of almost daily occurrence during the winter months.

Some very heavy snowfalls have been recorded; one or two which appear worthy of notice may be cited: at Palermo, N. Y., December, 1868, 68 inches fell, and at Quincy, N. H., February, 1887, 51 inches fell; at Highlands, N. C., December, 1880, 17 inches fell; at Montgomery, Ala., December, 1885, 11 inches fell.

Summer Snows.—On July 12, 1888, heavy snow fell over Mount Washington, N. H., reaching nearly to the base of the mountain.

On June 8, 1884, snow fell in Colorado, and at Lynchburg, Va., June 11, 1857, and June 12, 1887, and in the latter part of July, 1883, at Colebrook, Coos Co., N. H.

Snow Line.—On the high mountains even in the tropics the snow remains all the year, owing to the low temperature at the great height. The

snow limit, as observed on the mountains, is where the highest temperature of the year never sinks below 32 degrees. The height of the snow line in the tropics is about 18,000 feet and in the Rocky Mountains about 11,000 feet.

Colored Snow.—Where the snow lies unmelted from year to year it acquires a reddish, blood-like color. This color is due to minute organisms.

The White Appearance of Snow.—Snow is formed of an infinite number of very minute crystals or prisms, which reflect all the colors of the rays of light from different points; these colors uniting before they meet the eye, cause snow to appear white. Snow is a bad conductor of heat, so, when the earth is covered with snow it cannot throw off its heat by radiation; therefore, the earth is kept warm, and is nourished by the moisture which as it melts penetrates slowly into the soil.

Sleet.—Sleet is the condensation of moisture formed into small rain-drops, which in passing through a colder current before reaching the earth are frozen into small pellets. Some scientists contend that as soon as the rain-drop is formed it is carried upward by vertical currents into a higher and colder elevation and there frozen before descending to the earth as sleet.

No. 6. Cumulus

No. 7. Stratus

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

Hail.

Hail.—Hail is a rather irregular but generally round pellet of alternate layers of transparent and opaque ice. It is usually the size of a pea, but occasionally much larger.

Hail falls but seldom at any place; but it falls chiefly in the warmest places and at the warmest season and the warmest part of the day. It is generally preceded by an unusual degree of heat.

Hail usually falls during the passing of a local thunder-storm or tornado.

Hail falls but a few moments and never to any great depth; the greatest known depth was six inches over a very limited area.

Formation of Hail.—Hail is supposed to be formed by a general whirling of a belt of warm and cold air currents in the upper atmosphere. After the first course of condensation takes place, forming the initial body of snow or rain, it is successively whirled through an alternately warm and cold current; in passing through the warm current it takes on a coating of moisture, which in turn is frozen by passing through the colder current; this process continues until the hail-stones thus formed are thrown from the vortex or drop to the earth of their own weight.

Hail forms at a height of from 5,000 to 16,000 feet. The lower the elevation, the greater the size of the hail-stones.

Hail-stones 4 inches in diameter and weighing 18 ounces fell in New Hampshire on August 13, 1851.

During the passing of a hail-storm there is generally a loud crackling noise, probably due to the clashing of the hail-stones or to atmospheric electricity with which the air is charged. Lightning generally attends hail.

Dew.

Dew.—It is the general supposition that dew falls somewhat in the same manner as rain and is frequently spoken of as "falling dew."

Dew does not fall, but is formed on the ground or any substance, where there is a loss of heat by radiation sufficient to lower the temperature below the dew-point of the surrounding air; the warmer air passing over or coming in contact with the cooler ground, vegetation or any other substance causes the moisture in the air to condense on the cooler surface.

Dew forms in the night and occasionally in the day when the air is very damp.

Dew forms and has its heaviest deposits on clear, calm nights. Clouds retard and in most cases prevent the formation of dew. A strong wind which keeps the air constantly agitated prevents its formation; a slight wind, however, adds to the deposition of dew by a gradual renewal of the surface air. Anything which obstructs radiation, such as a covering of clouds or smoke or any artificial covering, prevents the formation of dew. If the air is very dry, no dew will form.

Dews are heaviest near large bodies of water, especially near the seacoast where the breeze is towards the land at night and the atmosphere moisture-laden.

Deposits of Dew.—The amount of dew which is deposited is occasionally sufficient to measure, but it rarely exceeds .02 of an inch under the most favorable conditions. Probably half an inch a year would be a fair allowance for places where the deposits are heaviest.

In California, during the summer, when there is little or no rain, the only moisture that sustains plant-life is from dew, which is frequent and heavy, owing to the favorable conditions of clear sky and light breeze from the ocean.

Frost

Frost.—The formation of frost is quite similar to that of dew, except that the temperature of the ground or surface material on which it forms must be at or below freezing point (32 degrees); then the moisture which is condensed forms in small ice crystals. Whenever the conditions are favorable and the temperature of the air is below 32 degrees, frost will form instead of dew.

Frost formation is prevented by high winds, clouds, smoke, haze, or an artificial covering.

Valuable plants and crops may be saved from frost by building fires to create smoke on the windward side of a farm or garden.

Light frost occurs when the temperature ranges from freezing-point to 4 degrees below freezing, and "heavy," black, or killing frost occurs when the temperature of the air a few feet above the ground falls more than 4 degrees below freezing-point. Many meteorologists contend that frost may occur with a temperature of the air a few feet above the ground from 12 to 16 degrees higher than the freezing-point. The writer, however, contends, after taking many observations along this line, that either light or heavy frost does not occur unless the temperature touches freezing-point. Whether it is

light or heavy then depends on the number of degrees the temperature falls below freezing point, and the duration of the low temperature.

Frost is more likely to occur in a valley than on high elevations, as the atmosphere is usually more quiet.

AVERAGE OF FIRST KILLING FROST OF AUTUMN.—The first killing frost of autumn has a wide range in dates of occurrence in all parts of the country, sometimes extending over a period of twenty-five days before or after the average of occurrence, which is here given for the various states.

September 1.—Extreme North Dakota.

September 15.—Northern Michigan, Central Minnesota and Central North Dakota.

October 1.—Maine, Vermont, Massachusetts, Central New York, Central Michigan, Southern Minnesota, Southeast Nebraska, Central Colorado.

October 15.—Southern New York, Southern Pennsylvania, Central Ohio, Central Indiana, Central Illinois, Central Missouri, Southern Kansas and Northern New Mexico.

November 1.—Maryland, Delaware, Southern Virginia, Northern Georgia, Central Mississippi, Central Arkansas, Oklahoma and Northwest Texas.

November 15.—South Corolina, Central Georgia, Central Alabama, Central Louisiana and Northern Texas.

December 1.—Northern Florida, Southern Louisiana and Southern Texas.

AVERAGE OF LAST KILLING FROST OF SPRING. —Average of last killing frost of spring occurs as follows:—

February 1.—Central Florida.

February 15.—Northern Florida, Southern Alabama, Central Louisiana and Coast of Texas.

March 1.—Coast of South Carolina, Central Georgia, Central Alabama, Mississippi, Northern Louisiana, Southern Arkansas and Southern Texas.

March 15.—South Carolina, Northern Georgia, Northern Alabama, Central Mississippi, Central Arkansas and Northern Texas.

April 1.—North Carolina, Tennessee, Kentucky, Southern Missouri and Northwest Texas.

April 15.—Southern New York, Central Pennsylvania, Virginia, West Virginia, Northern Kentucky, Central Indiana, Central Illinois, Southern Iowa, and Central Kansas.

May 1.—Southern Maine, Southern Vermont, Northern New York, Central Michigan, Southern Minnesota, Central Nebraska and Central Colorado.

May 15.—Northern Michigan, Central Minnesota, Northern South Dakota.

Frosts occurring before the dates here given are

likely to cause considerable damage to late corn in the corn-growing states of the west.

Frosts after April 1st are likely to cause great damage to wheat in the winter-wheat-belt of Illinois, Missouri and Indiana.

CHAPTER VIII

OPTICAL AND ELECTRICAL PHENOMENA OF THE ATMOSPHERE

THE most important of all the optical phenomena of the atmosphere is the diffusion of light, which is due to refraction and reflection.

REFRACTION.—By refraction is meant the bending of a ray of light as it passes from one medium to another. Air is a refracting medium, like water or glass; the more dense the air the greater is its refractive power. Consequently, that portion of the atmosphere at the earth's surface, being the most dense, possesses the greatest refractive power; its density gradually diminishes according to the elevation above the earth, until it becomes so rare, as scarcely to produce any refraction upon light. As a ray of light passes into a denser medium, it is bent towards the perpendicular. When it passes into a rarer medium it is bent from the perpendicular. Thus the rays of light continue above the horizon after the sun has gone down, and appear in the morning before the sun is above the

horizon. Refraction is easily demonstrated by placing in a glass of water a spoon, which will appear bent because the light (reflected from the spoon) is refracted. The effect of refraction is to make fish appear nearer the surface of the water than they really are and to make the sun, moon and stars appear higher in the heavens than they really are.

Colors of Light.—Light is divided into three parts: blue, yellow and red. These three colors make seven different combinations as follows:—1, red; 2, orange (or red and yellow); 3, yellow; 4, green (or yellow and blue); 5, blue; 6, indigo, (a shade of blue); 7, violet (or blue and red).

Prisms divide a ray of light into various colors, because all these colors have different refractive susceptibilities. Red is refracted the least and blue the most, therefore the blue color of the ray will be bent to the top of the prism and the red will remain at the bottom.

Transparency of the Air.—Substances that can be seen through are said to be transparent; in such substances every part between the two surfaces has a uniform refracting power, or in other words has in every place the same density and the rays of light emerge equally on the opposite side.

Substances that cannot be seen through are not

transparent, because the particles which compose them are separated by minute pores or spaces, which have a different density from the particles themselves; therefore the rays of light are reflected and refracted too often to pass through.

Inequality of Air.—Stars appear to twinkle because of the inequality and undulating motion of the moisture and dust particles in the atmosphere.

Reflection.—Reflection means the rebounding of light from the surface on which it falls. The reflection of light from the minute dust particles in the atmosphere is propagated from one dust atom to another, which diffuses and scatters the light received from the sun in all directions. The greatest amount of light is near the earth's surface, where the dust particles are larger than in the upper air.

On the days of greatest cloudiness, the multiplied reflections of the sun upon the dust particles in the atmosphere keep the day comparatively light. Some substances such as those with dull surfaces absorb the light, while those of bright or polished surface are good reflectors of light.

Colors of Rays of Light.—Each ray of light is composed of all the colors of the rainbow; some things reflect one of these colors and some another.

If this were not so, solar light would be of one color only and all objects would appear in that one color, or else black.

Blue Sky.—The sky is blue because the momentum of red and orange rays, being greater than that of blue, causes them to penetrate beyond the clouds, but the blue rays are stopped on their passage and reflected.

All objects appear black in the dark because there is no light to be absorbed or reflected and therefore none to be decomposed.

Why Vegetation and Plants are Green.—The leaves of plants are green because of a peculiar chemical principle called chlorophyll, formed within their cells, which has the property of absorbing the red rays and of reflecting the blue and yellow, which mixture produces green.

The leaves turn brown in autumn because the chlorophyll undergoes decay and is not replaced as it is in the spring.

Color of Clouds.—Clouds in the evening and morning are red on account of the red rays being the least refrangible, consequently the red color is the last to disappear in the evening and the first to appear in the morning.

Red Sun.—In hazy or foggy weather the sun

looks a fiery red because owing to the momentum of the red rays, they penetrate the dense atmosphere more readily than the blue or the yellow rays, which are either absorbed or reflected by the haze or fog.

This phenomenon is frequently observed in the "setting-sun."

MIRAGE.—Of the various optical phenomena, probably none appears more strange than the mirage, caused by refraction and reflection of light; the rays of light pass through layers of air at different elevations, one layer lying close to another of different temperature and density; where the contrast is very sharply drawn the rays of light passing through them will be reflected quite perfectly, causing an inverted image of distant objects on the surface of the earth or sea to appear in the sky near the horizon. A mirage seen from different heights changes the view. When above such a surface, one sees the objects beyond and above (but not below) reflected from it; but when one is below this surface, he sees the objects beyond and below (but not above) this surface, reflected from it.

A good demonstration of this may be had by placing a mirror in a horizontal position and look-

ing into it from above; then holding it horizontally overhead and looking into it from below.

Mirage is observed most frequently over dry, sandy soil; it is occasionally seen along the sea-coast and at sea, and is not uncommon in our south-western states.

Dispersion of Light.—Dispersion is the breaking up of the rays of light. Rays of light when passing through exceptionally minute atoms are so broken and scattered as to cause the color-producing rays partially or wholly to disappear.

The thicker and denser the atmosphere through which the sunlight passes, the more the colors are dissipated and lost. So when the sun is in the zenith the rays contain the most blue and when it is near the horizon, the most red. If there were no atmosphere, the sun would appear distinctly blue.

Rainbows.—Rainbows are produced by refraction and division of the sun's rays as they pass through mist or drops of falling rain. The colors or bands of colors thus produced are reflected to the eye of the observer. Rainbows are most frequent during the passing of local showers, and are most pronounced and beautiful when the clouds opposite the sun are very dark and the rain-drops large and uniform in size, and also when the ob-

server is on a line between the sun and the bow itself. The radius of the bow is from 40 to 42 degrees. There is sometimes a secondary bow with an outside radius of from 50 to 54 degrees. In one rainbow we see the rays of the sun striking the

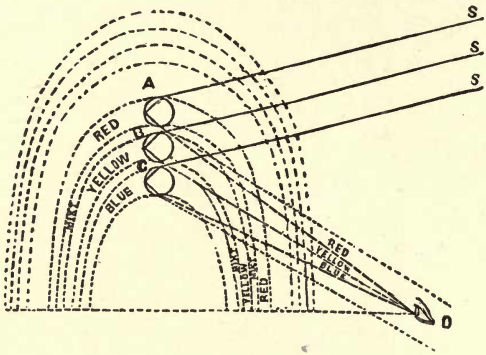


Fig. 1.

rain-drops from the top, and reflected to the eye from the bottom (Fig. 1); in the other we see the rays of the sun striking the rain-drops at the bottom, and then reflected to the eye from the top (Fig. 2).

The colors in the second bow will be seen in reverse order of those in the first.

Rainbows are seen when the sun is low, and the nearer it is to the horizon the greater will be the length of the bow; when the sun is close to the

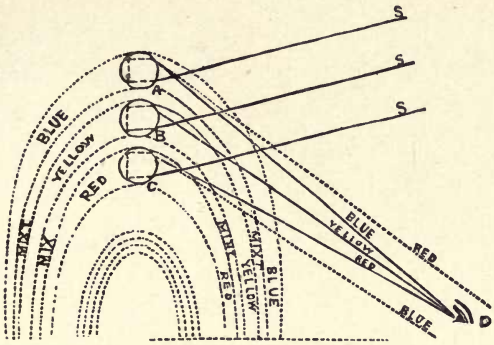


Fig. 2.

horizon the length or semicircle of the bow is 180 degrees.

Moonlight Rainbows.—Rainbows are occasionally seen by moonlight, but the colors are very dim.

From a high mountain or a balloon when the sun is near the horizon the complete circle of the rainbow may be seen.

Rainbows have no significance other than their appearance indicates that the rain has passed.

Rainbows seldom occur with conditions of extensive cloudiness or long-continued rains, but generally with the passing of local showers.

Atmospheric Electricity.—Atmospheric electricity has been given considerable study, but its

origin has never been established nor its force discovered. During the progress of thunder-storms it is made evident, when very great fluctuations occur. The atmosphere is generally charged with positive electricity, but it sometimes becomes negative, or there may be both positive and negative. This phenomenon, so far as known, has no especial bearing on weather or weather changes. Atmospheric electricity is made manifest in lightning and auroras.

LIGHTNING.—In clear weather the atmosphere is almost invariably charged with positive electricity; in cloudy and rainy weather the conditions may change with the greatest rapidity from positive to negative.

ELECTRICAL DISCHARGE.—The electrical discharge may take place between two clouds or between a charged cloud and the earth; in each case the path of least resistance is taken between the objects. The lightning flash is luminously heated air along the path of the discharge.

The atmosphere is always in an electrical condition, but substances vary greatly in their capacity for carrying electricity, when there is a difference of electric potential. The unit of electric potential is called the volt. Silver, copper and all metals are

good conductors, while glass, rubber, wool and dry air are bad conductors and resist rather than assist the flow of the electric current.

The electrical discharge between the clouds and the earth takes place more readily when the clouds are close to the earth, and a still more favorable condition is when rain is falling, which makes a perfect conductor from the clouds to the earth.

Classification of Lightning.—Lightning is classified as zigzag, sheet (or heat) and ball lightning. Zigzag lightning consists of plain broad streaks or flashes passing between two clouds or the clouds and the earth, with occasional arms or branches which spread from the main body or flash.

Sheet (or Heat) Lightning appears generally along the horizon causing an illuminous glow. Lightning of this character may be the reflection of lightning from a distant thunder-storm.

Ball Lightning appears as globes of fire which move very slowly, occasionally exploding with great violence. It is of rare occurrence and has never been satisfactorily explained.

The lightning flash is seen instantly because light travels about 186,000 miles per second.

Thunder.—Thunder is the crackling of the electrical discharge, which is probably occasioned

by the rushing together of the portions of the atmosphere that have been separated by the flash.

Sound travels about one mile in five seconds, so that if we count the number of seconds intervening between the time we see the flash and hear the thunder, we can tell the distance of the lightning flash from us.

St. Elmo's Fire.—This phenomenon is a silent luminous discharge of atmospheric electricity from projecting points, such as the tips of masts or yard-arms of vessels in low hanging clouds or in a storm at sea and most frequently observed in winter during a fall of snow.

Aurora Borealis.—The Aurora Borealis, or "northern lights," is an illumination of the sky in the northern heavens. In the southern hemisphere they are called Aurora Australis, or "southern lights." They occur in the middle or polar districts and with greatest frequency between latitudes 60 and 70 degrees north or south of the equator; they are rarely seen south of latitude 40 degrees and only infrequently north of latitude 80 degrees in the northern hemisphere. The aurora appears in various forms, such as an arch or bands of light, which span the sky near the horizon in an east-to-west direction, with streamers of white,

crimson or green light shooting intermittently to the zenith, the colors pulsating from a dim to a bright glow. They have variable dimensions and may be one thousand miles long and one or two hundred miles high. The belt of auroras in the northern hemisphere extends over the section of country of the greatest storm frequency and is attributed to atmospheric electricity or electro-magnetic conditions.

As yet no definite information has been brought to bear connecting auroral displays with general storms or weather changes.

Halos and Coronas.—Halos are circles seen around the sun and moon. Halos generally have a radius of 22 degrees, but may extend to 45 or 90 degrees. Coronas have a smaller circle, usually from 1 to 10 degrees. These circles are usually white, but sometimes colored.

The halo when colored has a red circle nearest the sun or moon and coronas have a blue color nearest the sun or moon.

Halos are more frequently observed than coronas and are formed by refraction and reflection of the solar rays from cirrus clouds, which are ice crystals suspended in the air at the higher elevations.

Coronas are formed by diffraction or interference

of light in passing through small particles of water in the upper clouds. The larger the particles of water the smaller the ring. Halos sometimes have a number of rings, sometimes they are separate and sometimes they intersect. At the points of intersection there usually appear bright circular patches of light called Sun dogs or Mock Suns.

Halos around the sun or moon are considered an indication of coming rain or snow.

CHAPTER IX

ATMOSPHERIC DISTURBANCES

In studying the laws of nature in relation to atmospheric disturbances we find that storms of a local or general character are brought about by an unequal distribution of heat over the earth's surface, causing unstable equilibrium of the air, which, in seeking to establish an equilibrium, keeps the atmosphere in a state of unrest, thus causing a constant change of barometric pressure over the globe, which is constantly increasing or diminishing at different places; thus disturbances form and move from place to place, the surface and upper winds undergoing transfer in horizontal and vertical lines, with precipitation of rain or snow according to the amount of moisture evaporated and liberated by condensation. Storm, as a scientific term, means wind,—winds of sufficient force to be dangerous to life and property. Precipitation of any character is never considered in the classification of storms.

In the United States the storms of which this book treats, may be classified as cyclones, anti-cyclones,

hurricanes, tornadoes, thunder-storms and dust whirls. All of these disturbances may readily be divided into two classes,—those of cyclonic motion (or low-pressure storms) and those of anti-cyclonic motion (or high-pressure storms). By pressure is meant the air pressure, its weight, measured by the barometer and given in inches and tenths of inches, as explained in a preceding chapter on pressure.

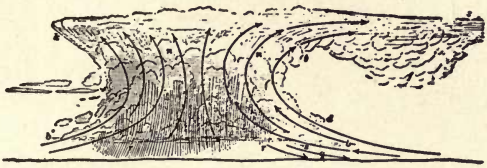
Areas of Low Pressure.—An area of low pressure is where the atmospheric pressure is least, or where the barometer reads the lowest, and is nothing more or less than a comparative vacuum in the atmosphere, into which the winds from all sides blow. The system of winds established by blowing towards the low-pressure centre is called the "cyclonic system," for the reason that they blow spirally inward and upward, with a motion contrary to the direction of movement of the hands of a watch and when nearing the centre the spiral motion becomes more pronounced. The influence on wind direction extends to the outer edge of the atmospheric depression, which may be limited to a few miles or may cover the entire country, depending somewhat on the depth of the storm centre, that is, the number of inches or tenths of inches below the normal (30.00 inches).

Incipient Tornado

Fully Developed Tornado

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

The deepest storms, however, are not always the ones of widest extent, although they show the greatest force.



Storm formation ascending column of warm air.

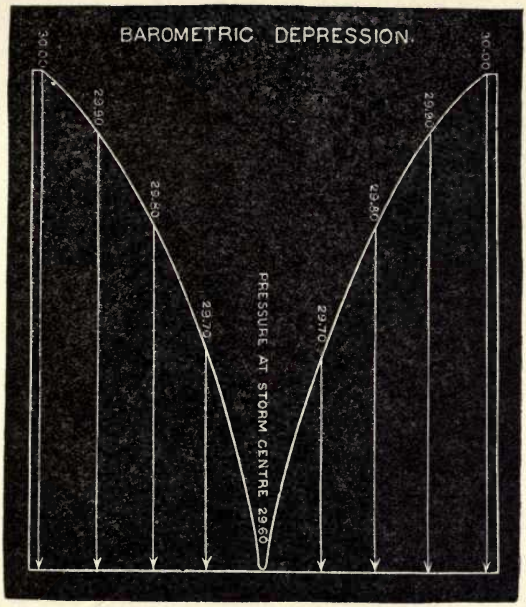
Cyclonic Features.—To understand cyclonic action we must study the characteristics of cyclones which embrace the fall in pressure preceding the approach of the storm centre and the general distribution of pressure along their paths; the temperature, humidity, kind, amount, extent, velocity and direction of upper and lower clouds; the amount of rainfall; the path of greatest precipitation; direction and velocity of the wind; the progressive and rotary motion of the storm centre and the configuration of the land over which these storms pass.

Distribution of Pressure.—The distribution of pressure from a central low area or cyclonic disturbance at the surface of the earth is a general decrease from the centre outward, which may cover a radius of from several hundred to two thousand miles. The pressure falls as the storm centre ad-

vances, the most marked fall being to the east of the centre. At times the barometric pressure on the eastern or northeastern side of a cyclone is much below the average, but only on rare occasions does it fall below 29.00 inches in the United States at sea-level and then only in the most severe storms.

Pressure Gradient.—The severity of all cyclonic storms is not definitely shown by an abnormally low reading of the barometer, but more especially by the pressure gradient. Pressure gradient indicates the change of barometric pressure in a given distance; the steeper the grade from the outer limits of the storm area to the storm centre, the greater will be the severity of the storm. In other words, if one should roll a ball down hill at an angle of 45 degrees, it would attain a certain velocity; if that angle were changed to 90 degrees, it would more than double its speed. It is the same with atmospheric air blowing towards a storm centre; the greater the difference in the barometric readings over a given distance from the centre to the outskirts of the storm, or from the normal of 30.00 inches, the greater will be the velocity of the wind.

The following table gives the different pressure



Comparative atmospheric vacuum at centre of cyclone.

gradients and corresponding wind velocities for a distance of five hundred miles.

Pressure Gradient Inches 500 Miles.	Wind Velocity in Miles Per Hour.
0.43	10
0.48	15
0.52	22
0.62	30
0.76	35

One inch pressure gradient for one thousand

miles would give a wind velocity of 50 miles an hour.

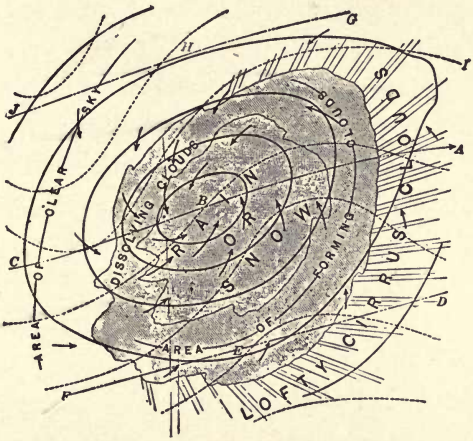
The steepest pressure gradient attending the movement of a cyclonic storm in the United States is found on the northwest side of the storm centre, consequently the highest wind is not felt on the approach of the storm centre, but immediately after the centre has passed.

The wind diminishes from the centre of the cyclone to its outer edge.

Storm Centre.—The storm centre is known by sailors as the "eye of the storm." At the centre of the cyclone the atmosphere for an hour or two in the most extensive storms becomes clear, the clouds disappear, the barometer shows a slight rise and to all appearances, except to the experienced observer, the storm is practically over; this condition changes after the storm centre passes, when the wind shifts from the easterly quarter from which it has been blowing to a westerly one and attains a greater force.

The peculiar phenomenon is probably due to the ascending current of air at the storm centre being dissipated by a descending current from higher altitudes, thus preventing the formation of clouds at that point.

TEMPERATURE ATTENDING CYCLONES.—The temperature on the eastern and southern sides of a cyclonic disturbance is warmest and generally much higher than the average of the place for the



Prevailing features and outline of a general cyclone.

season of the year; because the winds blow from a southerly and easterly, or warmer quarter, while on the western and northern sides of the storm they blow from the colder sections of north and west. This often causes a temperature of from 50 to 70 degrees higher on the eastern than on the western side of such depressions. Warm air waves

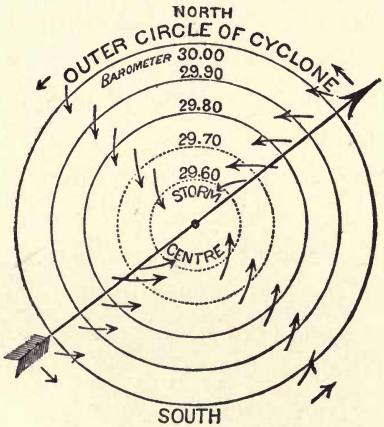
are sometimes felt a thousand miles in front of an advancing storm. The colder air following the storm is felt shortly after the storm centre passes.

Clouds Preceding Cyclones.—On the advance of a cyclonic disturbance the upper sky is usually covered for a distance of from 500 to 1,000 miles with cirrus clouds, which move very rapidly from a westerly or southwesterly direction, the direction from which the storm centre is moving; the lower, cumulus clouds, move rapidly in the opposite direction, or towards the storm centre. Rain falls from the nimbus clouds which float close to the earth's surface.

Movement of Cyclones.—The movement of all storms in the United States is from west to east, but is diverted slightly towards the north by the rotation of the earth. There is only one exception to this movement and that applies to hurricanes, and will be explained later. Although the general movement is from west to east, storms are frequently diverted from their course by the configuration of the land over which they pass and by waterways which draw storms in their direction.

The combination and position of cyclonic and anti-cyclonic areas quite frequently change the course of a general storm.

FORCE OF STORMS.—Storms move more rapidly in the United States than elsewhere; the average velocity is twenty-five miles an hour in summer and thirty-five miles an hour in winter. The velocity for different storms varies from 15 to 70 miles an hour. As a general rule, the most rapid-moving storms traveling over land are the most severe. It is not the progressive movement, but



Movement of air toward centre of cyclone in Northern Hemisphere. Large arrow shows path of storm.

the rotary movement, which creates the high and dangerous wind velocity. The slow-moving storms are usually the most extensive and their force may

be felt for hundreds of miles from the storm centre. Cyclones develop greater rotary force over the ocean because their form becomes more circular, on account of less obstruction and less friction. Over the land their form is distorted and irregular on account of friction with the earth; the lower winds passing over hills and mountain ranges undergo great changes, which, however, do not retard the progressive motion as they move faster over land than over the ocean. It is pointed out that low-pressure storms usually, but not invariably, follow the course of the upper wind or the direction of movement of the upper clouds.

There is a general increase in the force of winter storms from September to February and then a decreasing force from March to August.

Diameter and Shape of Cyclones.—The diameter of cyclones or low-pressure storms varies from 1,000 to 2,000 miles, with a slight increase over the ocean; they increase and diminish in magnitude and are sometimes entirely dissipated. They are generally of an elliptical shape with the major axis extending from W. S. W. to E. N. E., and their length usually twice their width. If they move with the broad side extending due north and south they may be several days in passing, but

Destruction by Broad Vortex Tornado

Exploded Houses

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

if they extend from southwest to northeast they move quickly and are of considerable force.

Rain Attending Cyclones.—Evaporation of moisture and condensation are the principal elements in the propagation of cyclones. The high temperatures preceding the storm on its eastern and southern sides augment rapid evaporation; the moisture-laden winds are carried towards the storm centre and by the ascending column of warm air, reach the upper colder air, where the moisture is condensed, the heat utilized in evaporation is released and the moisture which it held forms cloud or falls to the earth in the form of rain or snow according to the temperature and the amount of moisture condensed. Rainfall occurs most frequently on the side of the cyclone nearest the supply of greatest moisture. The quantity of rainfall depends entirely upon the moisture or dryness of the country over which the storms pass. In nearly all cases the heaviest fall of rain is found on the front or eastern side of the storm centre and the least on the western side. The path of heaviest rainfall is usually the path of the storm centre. It is seldom that the storm centre moves over a path of deficient rainfall, unless it be for some local cause, or unless it is deflected by an anti-cyclone or

area of high pressure from a natural course, as an area of high pressure offers great resistance to the movement of low-pressure storms.

Cyclones are slow in development and the rain area is not formed until the depression assumes well-defined outlines. The rain at first falls in scattered showers and may not occur until twenty-four to thirty-six hours after the storm begins to move.

The rain area is extremely irregular. The widest extent of rain is on the northeastern side and sometimes extends from 500 to 700 miles in advance of the storm centre and light rain but a short distance to the rear.

Cyclonic Paths.—As has been pointed out, the general movement of cyclones in the United States is in an easterly direction. Storms that enter our country from the North Pacific ocean move east to Montana, where some, of the least force, curve to the southward as far as Colorado and then to the northeastward, across the lake regions, and pass out the St. Lawrence valley; while those of greater force entering from the same point continue their journey due east to the St. Lawrence. Some of the storms that form in Montana or the Dakotas also move southward to Colorado, then northeast to the great lakes and out the St. Lawrence valley.

House Turned Upside Down by Tornado

House Thrown from Vortex of Tornado

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

LIBRARY OF THE UNIVERSITY OF

Storms that form in the Central Rocky Mountain States generally move to the east and northeast; those that form in the southwest generally move northeast, while those from the gulf coast move north-northeast.

Storms seldom cross directly over the Rocky Mountain range, except by great loss of energy; they also undergo great change in passing over the Appalachian system of mountains.

The tendency of storms to follow certain routes and the departures therefrom are well-marked features. There appears to be no certainty that they will follow any particular course.

A great number of storms developing in the United States find a birthplace along the southeastern slope of the Rocky Mountains and many in the northwestern states.

Storms are known to travel all around the globe, but the path of greatest frequency is the St. Lawrence valley.

The number of well-defined cyclones or low-pressure storms which cross the United States averages eight in each month from May to August inclusive, nine from September to November and in April; eleven in February, March and December and twelve in January.

It frequently occurs that two or even three cyclonic disturbances or areas of low pressure appear in different parts of the country at the same time, in which event they may pass off as separate depressions, but as a general rule they are drawn together, either making a more extensive or a more severe storm and sometimes both.

Paths of Cyclones or Low Pressure Areas.

ANTI-CYCLONES OR AREAS OF HIGH PRESSURE. —Anti-cyclones or areas of high pressure, have characteristics directly opposite those of cyclones or areas of low pressure, which are composed of warm, moist air and winds blowing spirally inward and upward towards the centre. The anti-cyclones or areas of high pressure are composed of cold,

clear, compact air and the wind flows outward in all directions from the centre, with the same direction of movement as the hands of a watch.

The eastern edge of the anti-cyclone which presses closely in the wake of the cyclone is often marked by a belt of rain or snow and high winds, due to the crowding of its colder air on the warmer, moist air of the cyclonic area. The main features of the anti-cyclone are well marked by clear skies, light winds and low temperature for the season. The clear weather and calm nights, with low temperature in the spring and fall, are favorable conditions for frost.

Regardless of the fact that light winds are a feature of the anti-cyclone, there prevail at times during the winter months severe winds, but only seldom accompanied by rain or snow.

The highest winds blow from the northwest when there is a low-pressure area to the southeast, but occasionally they blow strong from the northeast, especially when an area of low pressure is closely adjoining or to the southwest of the high area.

The centre of high pressure is calm, the winds, whether light or high, increase in velocity from the centre outward.

Intense High-Pressure Areas.—The most intense high-pressure areas occur in the winter and are marked by barometer readings of from 30.50 to 31.00 inches and attended by severe "Cold Waves," "Blizzards," and "Northers," which will be treated in subsequent chapters.

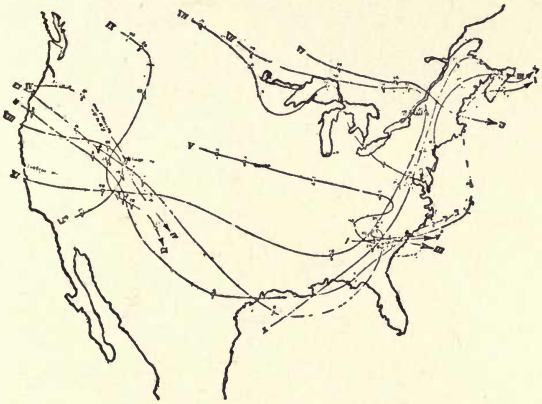
In summer months the high areas rarely have pressures above 30.50 inches.

Birthplace of High-Pressure areas.—In the majority of cases the anti-cyclonic areas enter our country from Manitoba or British Columbia; they come down fully formed over Montana, the Dakotas and Minnesota.

They move generally south or southeast and sometimes directly east. Their motion is spasmodic and uncertain, except when the pressure or barometer reading is abnormal and the whole area well defined; then there is a positive movement which is generally southward. Occasionally an area of high pressure will develop north of the great lakes and move southeast into the Middle Atlantic states; a few form in the northern and central Rocky Mountain states and drift eastward without any definite action or force.

Velocity of High-Pressure areas.—The average velocity of high-pressure areas is about 25

miles an hour; usually from 28 miles an hour in winter to 21 miles an hour in summer. Near the surface of the ground the direction of wind is



Paths of Cyclones or High Pressure Areas.

spirally outward from the centre, while at high altitudes it is spirally inward and vertical, down currents connecting the inflow from above with the outflow from below. The winds in anti-cyclones reach high velocities, but only immediately following the passing of a decided low-area storm. As a general rule, they are light to fresh winds; the highest wind is on their approach, or eastern side. In the summer months calms are very frequent during their existence.

They may be several days in passing over the country in winter, and several weeks in summer.

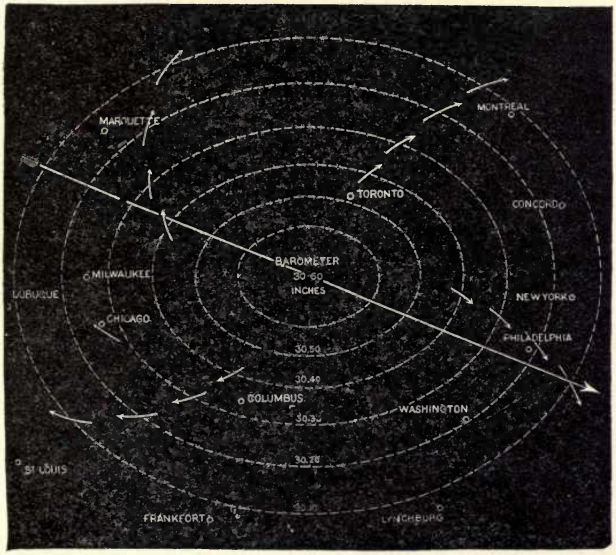
TEMPERATURE ATTENDING ANTI-CYCLONES.—The greater the density of the air, which is noted by the high readings of the barometer in approaching anti-cyclones, the lower will be the accompanying temperature of the air. At the centre of the high area the temperature reaches its lowest point and prevails with a north wind. The lowest temperatures recorded with anti-cyclones are those in the Dakotas, Montana and Minnesota and yet the anti-cyclone develops far to the north of these states.

To account for this peculiar circumstance, it is more than probable that in their passage southward the air becomes gradually colder as the area expands and the nocturnal radiation becomes greater and more rapid. Later, some of this cold is lost by passing still farther southward into a warmer section of country, where the radiation by night is overcome by the warmth of the sun. Thus the greatest cold pertains to the states mentioned, where the full development of anti-cyclones is reached.

DRYNESS OF ANTI-CYCLONES.—Anti-cyclones are characterized by dry, cold air. This is due to

the fact that as the air descends in these areas it is subjected to great compression by the piling up of colder air from above, which dissipates cloud and moisture and results in a low, relative humidity. Any increase of pressure causes a higher barometer and correspondingly dryer air.

Distribution of Dry Air in Anti-Cyclones.—It is estimated that the diameter of the larger high pressure areas of winter vary from two



Anti-Cyclone or Area of High Pressure. Large arrow shows general path from northwest to southeast. Small arrows show winds blowing out from centre.

to four thousand miles, while those of summer vary from one to two thousand miles. They occur more frequently in the higher or middle latitudes and are about forty per cent. less frequent than low-pressure areas. They increase in numbers from about five in each of the summer months to eight in each of the winter months.

Hurricanes.

Hurricanes.—The difference between a cyclone and a hurricane consists chiefly in the location of development and as a general rule a greater wind force which occasionally attends the movement of the latter. These whirling monsters are technically called hurricanes in the West Indies, typhoons in the China Sea and cyclones in the United States.

The hurricane has characteristics which distinguish it from all other low-pressure storms.

Hurricane Development.—These storms develop in the southern region of the zone of easterly trade-winds and generally east of the Windward Islands or on the border of the torrid zone or equatorial belt of calms, which ranges close to 10 degrees north latitude. The belt of calms or "doldrums," as they are sometimes called, extends in

August and September from 3 to 11 degrees north latitude on the Atlantic Ocean and from 7 to 10 degrees north latitude on the Pacific Ocean.

HURRICANE FORMATION.—The cause of formation of West Indian hurricanes is not fully understood, although they possess the general features of low-pressure storms. It is the consensus of scientific opinion that, owing to regions of excessive moisture and abnormal heat in which they form, there is an inward and upward flow of warm, moist air to the place of greatest heat, which starts in a small way, gradually expanding and gathering force from its condensation of moisture until the upper winds carry the general column of ascending air beyond the region of calm and a mighty storm is started on its way. The surface winds blow spirally inward and upward, with increasing force after the vortex begins to move. These storms are probably in the process of formation for several days or maybe weeks before any movement is noted; during this time the evaporation of moisture is excessive and in consequence the rainfall along their paths is always very heavy.

HURRICANE SEASON.—The season of West Indian hurricanes is from July to October, inclusive; August and September are the months of greatest

frequency. They occasionally occur in other months than those mentioned.

Hurricane Paths.—Hurricanes after starting pursue a course to the westward, which is opposite to the motion of all low-pressure storms; they are at first carried in the westerly direction by the upper air currents, but when brought under the influence of the surface winds, about latitude 30 degrees north, they recurve to the north and east and pursue that course; if they recurve in the Gulf of Mexico and the centre of the storm approaches the gulf coast to the west of the Mississippi River, their force is generally dissipated before they pass any great distance inland. If they recurve to the east of the Mississippi River and reach the Atlantic coast, they then pursue a course nearly parallel with the gulf stream until near Cape Hatteras, when they swerve more to the east, but their force is usually felt all along the Atlantic coast.

Diameter and Force of Hurricanes.—Hurricanes have a diameter varying from five hundred to fifteen hundred miles, but the region of hurricane winds, which is a circle or oval-shaped area, rarely exceeds three hundred miles in diameter; the wind in this area blows in a rotary motion from fifty to one hundred miles an hour and if the storm

is on the coast it may extend inland for a distance of one hundred miles from the storm centre.

The hurricane paths are extremely long in comparison to the width of the storm.

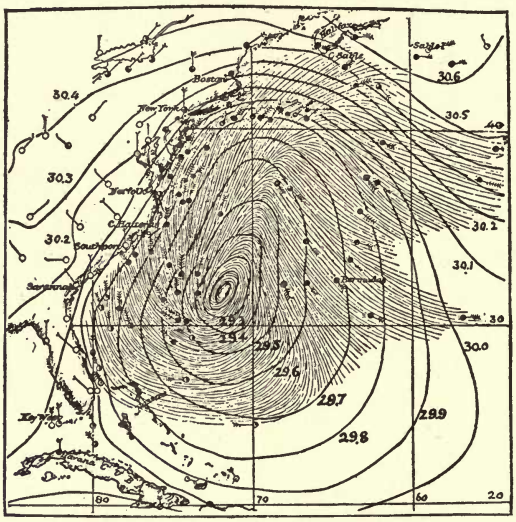
Progressive Motion of Hurricanes.—The progressive motion of West Indian hurricanes in their westward movement is about 15 miles an hour; at the point where they recurve the movement is greatly retarded and they sometimes remain stationary for a day or two; on the northeast path the velocity increases, but the body of the storm expands while the rotary motion is somewhat diminished without, however, weakening their destructive power.

Many of the hurricanes lose all their force as soon as the centre passes inland; several, however, have traversed the country from the Gulf states to the New England coast overland with great force.

Atmospheric Conditions Preceding Hurricanes.—In advance of an approaching hurricane the barometer reading is generally above the average; the higher above the average before the storm, the greater will be the fall and the stronger the force of the wind.

The first intimation of the coming storm is probably observed in the clouds, which precede its centre

for a distance of 500 miles or more. The cirro-stratus ribbons, or strips of white feathery and delicately shaped clouds, are the forerunners of these severe storms and indicate the path of the storm



Tropical Hurricane. Covering the Atlantic from Cuba to Nova Scotia and to several hundred miles east of the coast line.

centre. The atmosphere becomes hazy and near the horizon the rising or setting sun through this veil of haze appears an intense red. As the storm approaches the sea, which has been quite calm, becomes ruffled, the wind begins to brisk up as the

barometer begins to fall and the air becomes warm and stifling.

Rain, Thunder and Lightning with Hurricanes.—Heavy rain and occasionally thunder and lightning are the accompaniments of a tropical hurricane. The rainfall is very heavy; often as much as 4 or 5 inches falls at a place in as many hours; the down-pour is quite general all along its path; the atmosphere is so charged with moisture that the clouds move very close to the earth and during the passing of the storm it is very dark even in the middle of the day; over the ocean it would be difficult to draw a contrast between the sky and the sea.

When thunder and lightning are observed in a hurricane it gives a feeling of relief, for it is an indication that the storm's force will be moderate.

The principal force in hurricane winds is apparently in the lower air strata, for their formation is very much broken in coming in contact with hilly country.

CHAPTER X

LOCAL STORMS

Of all the powerful manifestations of nature, the most violent and destructive is probably that displayed by the tornado, save possibly in some instances by an earthquake. The latter, however, are of rare occurrence, while the former are of frequent occurrence in the United States.

Tornado.—The tornado is the most diminutive and yet the most powerful and destructive of all storms. It is of local origin; limited in width and length of its path, its chief characteristic is a funnel-shaped cloud, which dips to the earth's surface and has a violent rotary motion. The upper, surrounding sky is covered with a mass of black, treacherous-looking clouds.

Formation of Tornadoes.—Many theories have been advanced in regard to the formation of tornadoes, but the most probable and generally accepted one is that when an area of low pressure passes over the country the general circulation of wind from all sides flows towards its centre, which

brings the colder dry winds from the north and west and the warmer moist winds from the south and east into the general circulation of air bearing towards the central point, or general storm centre. It is the belief that in this rush of warm and cold air there must be a point of meeting where there is a great difference of temperature; in which case the warmer current underruns the colder layers of air and in seeking an outlet forces its way through the place of least density, causing a violent upsetting of the atmosphere, which results in the formation of a funnel-shaped cloud by the condensation of moisture from the uprushing of warm, moist air through the colder layers to a higher elevation, where the cloudiness is more profuse owing to the less dense air and more general condensation. The greater the difference in the temperature between the warmer and colder air layers, the greater will be the violence of the rotary motion which takes place at and in the immediate vicinity of the vortex. As soon as the temperature in this whirling column and that of the different layers of air near the earth's surface become equalized the storm ceases, with greater suddenness than it began.

The difference in temperature between the central column of warm air and the colder air which

surrounds it is essential for the development and continuance of the storm. The more moisture that is carried up by this central draught, the more latent heat is liberated, which again becomes sensible heat through the action of condensation, and adds force to the central column to promote storm action. When the upflow of warm, moist air ceases, the storm is at an end.

Tornadoes are of local origin and occasionally develop with the assistance of the general circulation of wind around a low-pressure area. Local winds may promote their development, but under such circumstances they are not of great force.

Conditions Preceding Tornadoes.—Prior to the formation of tornadoes, the day is very warm and the atmosphere very oppressive, but clear, with a very mild south wind blowing towards the low-pressure centre, which is generally several hundred miles to the north. About the warmest part of the day, light, fleecy, cirrus clouds are observed moving in the same direction as the surface winds. Finally there appears to the southwest a light gray ball-like mass of clouds, which lead to a treacherous greenish-black cloud with a funnel dipping down; at times reaching the earth and swaying from side to side. As it advances a cloud of dust fills the air

and there is a terrible roar, which has been compared to the noise which might be produced by the rumbling of thousands of trains of cars passing through a tunnel at the same time; it is positively deafening. This terrific noise usually occurs about fifteen minutes before the arrival of the tornado and gives warning of its approach. Its cause has never been definitely determined, but may be due to friction caused by the violent rotary motion of the tornado funnel.

Tornado Dimensions and Paths.—The terms "tornado" and "cyclone" are synonymous in one sense only, in that they apply to storms of gyratory or whirling motion, where the wind blows spirally inward and upward. Their main features present a great contrast, and still the terms are used indiscriminately. The cyclone is a wide-area storm covering from 500 to 2,000 miles; with brisk to high winds extending from its centre to the outer edge.

The tornado, in comparison, is a most diminutive storm, the width varying from 50 to 1,000 feet. Tornadoes travel a distance of from 1 mile to 200 miles before being dissipated.

Tornado paths are found several hundred miles to the south or southeast of general low-pressure

storms. Tornadoes invariably move from the southwest to the northeast.

Progressive and Rotary Motion of Tornadoes.—The progressive movement of tornadoes varies from 10 to 100 miles an hour, with an average of about 40 miles an hour. The movement is not a steady one. At times they have appeared to be stationary, when they would suddenly move with great rapidity.

The rotary motion is the dangerous and destructive element; the velocity has never been determined, but it is safe to say that, from the most scientific estimates, it ranges from 300 to 500 miles an hour; not less, and probably much higher.

These destructive winds can be determined only by the strength and weight of objects which have been destroyed, or moved from one place to another. The great force or velocity is in the central vortex or funnel, which dips down, causing devastation wherever it touches,—uprooting trees, leveling houses, lifting bridges and large buildings from their foundations, blowing trains of cars from their tracks and even lifting engines several feet and throwing them to one side. No power has ever resisted the force of a tornado, except a mountain range.

The path of the tornado is very sharply defined, the destruction is clean-cut and thorough.

To be within the tornado path is almost certain death, but on the south side, one may stand within a distance of 500 feet with impunity ; on the north side the destruction is greatest and it would not be safe to be within a thousand feet of its path.

Hail, Lightning and Rain in Tornadoes.—Tornadoes are almost invariably attended by a very heavy fall of hail; which is probably the result of the drops of moisture formed by condensation in the up-current being rapidly and successively whirled through the warmer and colder belts of air, taking on coat after coat of moisture and frost alternately until the hail-stone becomes of sufficient size to fall of its own weight or is thrown from the vortex. Hail of the tornado is usually of very large size and falls immediately after the tornado funnel passes, except occasionally when it precedes the wind.

Rain invariably precedes the tornado from ten to twenty minutes.

There is generally a very brilliant electrical display, and in the most severe tornadoes it would seem as if the entire heavens were lighted up by internal fire.

Time of Tornado Occurrence.—Tornadoes almost invariably form about or shortly after the warmest part of the day; the majority occur between 2 and 5 P. M. Tornadoes occur in every month of the year; their number in the winter months is very small; they occur with greatest frequency in April, May, June and July; during these months the records show that they average about seven or eight each month; in the other months from one to six. Tornadoes which may be classed as very severe occur very seldom; there are not more than one or two a year over the whole United States. Extremely destructive tornadoes, in which there is a great loss of life and property, occur not more than once in five or six years.

Explosions in Tornadoes.—Explosions like the report of cannon are frequently heard during the passing of a tornado. These noises remained a mystery for a long time. They are now accounted for in this way: It is known that there is a very great fall in the barometer at the centre of the tornado; the exact fall will probably never be known, but it is sufficient to cause a partial vacuum in the atmosphere, so that when the centre of the tornado passes over a closed house, for instance, all or nearly all the air is withdrawn from the outside,

while the air inside expands, causing the house to explode, thus accounting for the report.

It is estimated that the normal air pressure at the surface of the earth, which is 14.7 pounds per square inch on all sides of a body, is suddenly reduced at the centre of the tornado to probably one fourth of this amount, which leaves it 3.7 pounds per square inch, or 533 pounds per square foot. The pressure then at normal on the inside of the closed house would be 2,117 pounds per square foot, making a difference of pressure exerted from the inside over that on the outside of 1,584 pounds per square foot.

It has been found that one, or even two or three rooms of a house have been exploded and no other part of the house disturbed. Houses where the windows and doors are open, giving the air an opportunity to escape very readily, never explode.

States of Tornado Frequency.—Tornadoes occur most frequently in the states bordering the Mississippi and Missouri rivers, principally in Kansas, Iowa, southern Minnesota, Missouri, Illinois, Wisconsin, Mississippi, Arkansas, northeastern Texas, northwestern Alabama, Indiana, South Dakota, western Ohio, and in scattered parts of Georgia, Michigan, Pennsylvania, New England and New York. They seldom occur west of the 102d

meridian, southwest Texas, Florida or along the Atlantic coast.

Suggestions for Safety in Case of Tornado.—It is well for persons living in the states of tornado frequency to familiarize themselves with the atmospheric conditions which usually precede these storms. Should they then find themselves in the path of a tornado, they must bear in mind that hasty action is necessary. If they see the dark greenish cloud to the southwest, it is safest to run to the northwest or southeast. If the funnel cloud is on the east, north or directly south of them for a distance of a thousand feet or more, there is no danger, as their path is from southwest to northeast. If one has not time to escape from the house, seek safety in the southwest corner of the cellar if it is a frame house, or some hole in the ground, and lie down flat. If the house is of brick or stone, do not go to the cellar, but preferably lie flat on the ground in the yard or an open field.

Thunder-Storms.

Thunder-Storms.—These storms partake somewhat of the nature of tornadoes and the most severe might well be termed incipient tornadoes. They are of local origin, travel from one mile to 100

miles and are attended by rainfall, sometimes hail, and more or less thunder and lightning; at times the winds and lightning are dangerous elements; but they lack the violent rotary motion of the tornado. They occur in nearly every state in the Union with more or less frequency.

CAUSE OF THUNDER-STORMS.—Thunder-storms are caused by an ascending flow of warm, moist air and a descending flow of cold air. Their formation depends largely upon the amount of heat and moisture in the lower air. When warm, moist air rises and there is a decrease in temperature of over half a degree for every 100 feet of ascent, the equilibrium of the atmosphere is upset and a rapid change takes place. There is a rotary and a progressive motion to thunder-storms similar to that of the cyclone, where the winds blow spirally inward and upward towards a central column of ascending air.

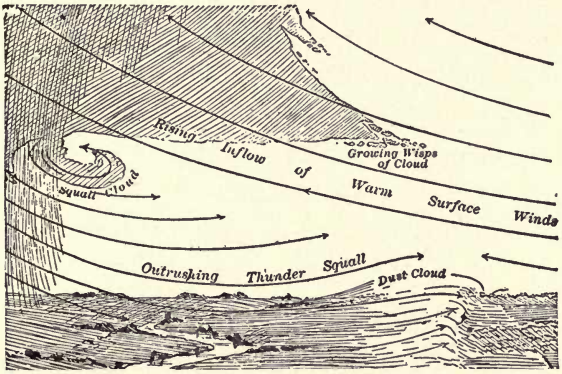
FORMATION OF THUNDER-STORMS.—They form usually at or shortly after the warmest part of the day; if over a flat country, the initiatory column of warm air starts over the warmest spot; if in a hilly or mountainous section, the warm, moist air flows up the sides of the hills or mountains, which is all that is essential to start a thunder-storm.

At first the winds are light and the air warm and sultry; dark clouds, with rather rounded tops and a broken flat base, form low in the western sky; these clouds steadily rise towards the zenith, without any special disturbance being observed; they drift along, gradually increasing and expanding; preceding and far above the rounded mass of cumulus clouds is seen the fine feathery cirrus clouds, distinctly separate from the lower clouds. As the lower clouds come nearer they become a grayish white—changing to a dark gray. The first thunder is heard coming from the cumulus clouds and from 5 to 20 minutes afterwards there is a rush of wind along the surface, which comes from underneath the main clouds or from what is called the squall cloud; a few minutes after the wind, comes the rain. If the wind comes before the rain, the storm may be quite severe but of short duration; if the rain comes before the wind, the storm may not be severe, but it will last longer.

The rainfall in most thunder-storms is heavy for a short period; it often happens that as much rain falls in a heavy thunder-storm as would equal the average monthly measurement for that place, especially in the Southern States and along the South or Middle Atlantic coasts.

As a rule, thunder-storms seldom last more than two hours; the average length of time is about one hour.

Relation of Thunder-Storms to Low-pressure Areas.—Thunder-storms hold the same relative position as tornadoes to general and ex-



Thunder-storm formation and advance movement.

tensive low-pressure areas; they form on their southern or southeastern quarter and generally travel northeastward and they last as long as there is a new supply of warm, moist air flowing towards the central column of ascending air in the lower atmosphere.

Thunder-storms occasionally divide and undergo translation over two separate paths; especially is

such a feature noticeable in the vicinity of New York City; one section of the storm will pass up the Hudson Valley, while the other follows Long Island Sound or along the South Coast of Long Island. Heavy rain may fall along their paths and the intermediate county remain dry.

Two Classes of Thunder-Storms.—Thunder-storms may be divided into two classes:—First, heat thunder-storms, which are of the summer type; second, cyclonic thunder-storms, which occur mostly in autumn and winter, in the neighborhood of the ocean or gulf coasts.

Heat or summer thunder-storms occur principally when the sun is above the horizon, and occupy the lower air strata; never having any great altitude they form and move without any definite relation to the general low-pressure areas and are in most cases of limited extent. If streamers are observed from the upper cirrus clouds, which attend their progress, there will probably be a heavy down-pour of rain and a very brilliant electrical display, with loud peals of thunder; should these streamers be lacking these unusual features will also probably be missing.

In the cyclonic thunder-storm not so much depends on the heat of the day as on the warmth of

the general atmosphere. They form principally after the sun is below the horizon and only when there is an area of low-pressure to the west or northwest and invariably in the southeast quadrant of the general low area. They are the larger and more enduring storms, and extend higher in the air. The local configuration of the land offers little resistance to their passage, which shows that they are controlled or carried along by the air of the higher elevations and travel in a sort of band, broad side foremost.

Movement and Distribution of Thunder-Storms.—Thunder-storms have a progressive movement from 20 to 25 miles an hour.

They begin in a small way, gradually expanding and broadening and sometimes present a front extending from 2 to 100 miles; the direction of movement of summer thunder-storms is in conformity with the general surface winds, while the winter storms are governed by the direction of the upper winds.

Thunder-storms are most frequent near the equator and decrease with the distance to the north; they are more frequent in summer and less frequent in winter. Florida and the lower Mississippi valley probably have the greatest number in

the United States, the average annual number being from thirty-five to fifty; in the Middle States the number is reduced to twenty and in the states farther north to ten; they are probably least west of the Rocky Mountains. In southern California they are of rare occurrence.

Lightning Discharge and Thunder.—The manifestations of atmospheric electricity are apparent in all thunder-storms. The lightning discharge from cloud to cloud or from the clouds to the earth lasts but the millionth part of a second.

Thunder is due to the electrical discharge causing an instantaneous heating of the air and the rush of colder air to path of warmer air along the line of discharge.

Thunder is rarely heard for a distance greater than ten miles. The velocity with which sound travels depends upon the temperature; at 50 degrees it would travel 1,107 feet per second, with an increase of about one foot for every degree above or below that for ten or twenty degrees.

Conditions During Thunder-Storms.—Just prior to the thunder-storm the wind is light, the air comparatively dry and the relative humidity decreasing; high temperature and falling barometer are the invariable features. As soon as the storm

breaks, there is a rapid fall of temperature, rapid rise of the barometer and relative humidity and high wind, which as a general rule subsides after the first great burst. Thunder-storms in nearly all instances are very beneficial in relieving the atmosphere of excessive heat and sultriness; but in some cases the air after the storm appears more suffocating than before; this is caused by the atmosphere being overcharged with moisture. The moisture that is condensed as rainfall is that which the air contained at the time of the greatest heat, so that when the temperature is reduced the capacity of the air for holding moisture is correspondingly less, which leaves the air containing as much, if not more moisture, according to the temperature than before the storm. A second rainfall usually brings general relief.

Danger in Thunder-Storms Along Waterways.—It is a well-known fact that thunder-storms are more dangerous over waterways than over dry land. Thunder-storms follow a river because the water is a good conductor of electricity; over a river the lines of electrical force are concentrated between the low-hanging clouds and the water, which creates an electrical disturbance of greater energy than is observed over the land; this

accelerates the wind's force and the danger to small craft becomes very great. It is always well for those on the water to seek a place of safety as soon as a thunder-storm is seen forming. It is but foolhardy for any small boat to remain out and take chances when a harbor of safety can be reached. The larger vessels sometimes have a most difficult time in weathering these severe local squalls.

Water-Spouts.

Water-Spouts are an incipient form of tornado. They form over the water and possess considerable force at times, but as a general rule are of no great intensity. They have a long funnel which reaches from the cloud bank to the surface of the water; the funnel is formed by a rapid inward and upward spiral motion of the lower air; the suction power at the centre is sufficient to draw a column of water for some distance into the air; the water near the spout for a very short distance becomes very much agitated. Water-spouts are short-lived and move but a short distance.

CHAPTER XI

WEATHER MAPS

THE development, movement and general features of all atmospheric conditions which prevail in our country and the resulting changes therefrom from day to day, are best portrayed by the daily weather map, issued by the United States Weather Bureau, under the direction of the Secretary of Agriculture in pursuance of an act of Congress.

From these maps, any intellectual person, with a general knowledge of the laws of storms of high and low pressure as herein described, may prophesy with a fair degree of accuracy coming weather changes for one or probably two or three days in advance.

THE WEATHER MAP has for its base a topographical and complete outline of the United States. The observations of the weather taken daily simultaneously at 8 A. M. at the various stations throughout the country are telegraphed to New York, Philadelphia, Boston and many of the larger

stations where these maps are issued, within twenty minutes of the time the observations are taken. As the reports are received at the various points they are entered on the map which is printed and distributed free of cost to business houses, corporations, institutions, schools and other places, where they may be of benefit.

The data entered on the map comprises the reading of the barometer (or atmospheric pressure), the temperature, state of the weather and direction of the wind.

Outlining Storms or Areas of High and Low Pressure.—The distribution of atmospheric pressure is continually undergoing a change from day to day at all places. To learn the nature of such change, it becomes necessary to trace the lines of the progress of storms or the change of atmospheric conditions from day to day, and by thus considering the past and applying our knowledge of the laws of storms, the weather of the immediate future may be more easily determined. Stations of observation of the United States Weather Bureau are scattered over the country from the Atlantic to the Pacific oceans, and from Canada to the Gulf of Mexico. These stations being at different elevations, the reading of the barometers would neces-

sarily be at variance; those at the higher elevations would read lower than those at sea-level under the same atmospheric conditions, owing to the less density of the air. It is obvious, therefore, that to eliminate the inequality of elevation all barometer readings are reduced to the standard of sea-level. Corrections are also applied for temperature to allow for the expansion or contraction of the barometric column by heat or cold. For this reduction the standard of freezing point has been adopted. With these local differences eliminated, the barometer readings, as they are used, represent the true weight of the air as it would be observed on a level surface at a uniform temperature.

Barometer Lines.—When these barometer readings are entered on a map, lines are drawn for a difference of every one-tenth of an inch and connect all places having the same pressure. It is found by continuing these lines, beginning from the normal pressure of 30.00 inches, to that of lowest pressure and to that of highest pressure, that circles or oblongs have been formed, which completely enclose and distinctly outline the areas of high and low pressure.

The barometer or lines of equal pressure are the solid lines, with the height of the pressure noted at

the ends or within the lines when the circle is complete. The cyclonic or low pressure has its centre marked with the word LOW. To signify the anti-cyclonic or high-pressure centre, the word HIGH is used.

The atmospheric pressure, as outlined on these maps, is the most important element considered by the forecaster; the translation of the barometric high and low centres from place to place, form the basis of all calculations.

TEMPERATURE LINES.—The temperature lines are called isotherms; they are dotted lines drawn for a difference of every ten degrees and connect all places having the same temperature. The number of degrees for which they are drawn is noted at the end of the lines.

They readily indicate the degree of heat and cold in the various parts of the country each day. By a comparison of these lines, the advance of warm or cold waves may be determined.

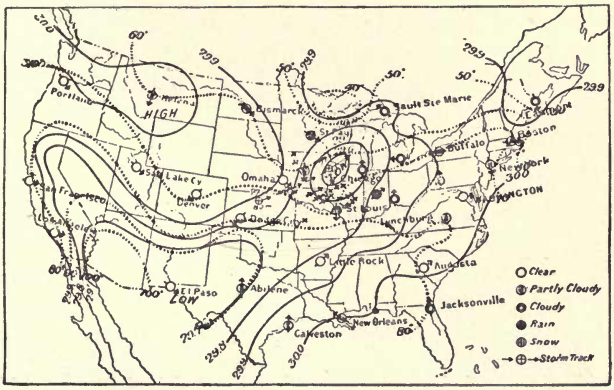
WEATHER DISKS AND ARROWS.—To indicate the weather at each place, small disks forming a circle are used. An open circle indicates clear weather; a circle half black indicates fair weather; a circle completely black indicates cloudy weather; a circle with the letter (R) in the centre indicates

rain; a circle with the letter (s) in the centre indicates snow.

Arrows passing through the centre of the circles fly with the wind indicating the direction from which the wind is blowing. (Arrows on the housetops point to the direction from which the wind is blowing.)

The object of the arrows flying with the wind is to show the direction of wind flowing into an area of low pressure and define its centre by this means, as well as by the lowest pressure reading, and likewise to show the path of the wind flowing out from an area of high pressure.

With these combined features of atmospheric conditions so graphically presented, there is no



reason why the layman should not be able to master the general method of forecasting the weather by this means.

In case, however, that a weather map is not available, other and simpler methods of forecasting will be pointed out in subsequent chapters.

This map gives a graphic representation of the weather conditions over the United States on the evening of May 27, 1896, the day of the St. Louis tornado, as shown by observations taken at Weather Bureau stations at 8 P. M., seventy-fifth meridian time. The heavy lines, called *isobars*, are drawn through points having the same atmospheric pressure, as shown by the readings of the barometer, a separate line being drawn for each tenth of an inch in pressure. The dotted lines, called *isotherms*, are drawn through points having the same temperature, separate lines being drawn for each ten degrees. The direction in which the wind is blowing is indicated by the arrow, which is represented as flying with the wind. The state of the weather is indicated by the symbols, which are explained on the map.

The map shows an area of low pressure, constituting a well-defined storm, central over eastern Iowa and northwestern Illinois, having moved

thence during the day from Nebraska and Kansas, where it was central on the morning of the 27th. Tornadoes and violent local storms occurred in localities in the southern and eastern portions of the general storm area at points marked on the map with a cross.

Practical Forecasting by Use of the Weather Map.—To the layman the daily weather map presents the appearance of Chinese hieroglyphics; the intertwining of lines gives one a feeling of confusion in an attempt to understand them, but after a few moments of careful dissection of the different features, one by one, the eye readily distinguishes and the mind perceives the underlying principle of the whole system which becomes decidedly interesting, clear and comprehensive and there is a feeling of eagerness to pursue the subject.

Development and Movement of Low-Pressure Storms.—It is generally believed that storms make a complete circle of the earth, being at times broken and disrupted, frequently dividing and traveling as distinct depressions; again we find them coalescing and moving with renewed force as one storm, each area of low pressure being separated by areas of high pressure from its preceding or

succeeding low pressure area. Thus we find the storms of the United States passing over the country with a general direction from west to east; the majority of them entering from the northwest, frequently moving at first in a southeasterly direction and then in a northeasterly direction; while those which are found entering or developing in the extreme west or southwest move northeastward over the central states to the lake regions and out the St. Lawrence valley. Storms approaching the gulf coast usually move first westward then eastward to the borders of the Atlantic coast, where they turn to the northeast, following a line parallel to the Gulf Stream; occasionally the storms from the south pass almost due north to the lake regions or the vicinity of the central states before they turn to the northeast; this is due in part and in most cases to the existence of a low-pressure area in the north, with a trough of depression extending well to the southward, which reduces the resistance of the air and opens a passageway for the advance of the southern storm; otherwise a more natural course towards and along the border of the Atlantic coast would be pursued.

But few storms come in from the Gulf of Mexico to the west of the Mississippi River, and in such

cases their force is expended over Texas; they may pass inland as weak depressions and regain some of their lost energy in the lake regions. Storms may form in any part of the country, but they seldom find a birthplace in the states east of the Appalachian system of mountains, for the reason that the atmosphere is almost constantly in motion; the air is not allowed to become heated to a density sufficient to rise, before it is blown away, thus preventing, to a great extent, the formation of general storms, but permitting principally the formation of local showers or thunder-storms. General storms reaching to the east of these mountains usually have their force accelerated and pass on their course with increased energy.

It is evident that wherever storms develop or whatever may be the point of entrance, whether from the Pacific Ocean, the northwest or the Gulf of Mexico, the objective path moving from all directions is from west to east to a point north of east; for that reason, all the storms from the west or southwest of the Mississippi and throughout that valley find a path over the lake regions, and leave the country by way of the St. Lawrence valley, their southern side sweeping New England; while the storms which develop or enter to the east of

the Mississippi River in the south or along the Atlantic coast usually follow the coast line, and either branch to the eastward from the coast at Hatteras or follow the coast to Nova Scotia.

The path of country extending from the lake regions over the St. Lawrence and northern New England experience more storms than any section in the world.

The extreme western and southwestern states and the Plateau regions of the Rocky Mountains are the sections of most frequent storm development.

Throughout these regions the air stands quietly and principally over a flat surface where it becomes quickly warmed; the accumulation of heat goes on until the mass becomes so great that it begins to rise, forcing its way through the upper layers of cooler air to a great height by the impulse of the warm air at the surface.

The ascending column forms a partial vacuum into which all the warm air from the surrounding surface flows. The rising warm air attains a whirling motion, which continues so long as the heat from the surface lasts and if in sufficient quantity, the whirling motion established is brought under the influence of the upper air currents and is car-

ried forward by the assistance of the rotation of the earth. Storms of this character may last but a few hours and disappear with the setting sun; many, however, attain proportions sufficient to be classed as full-fledged cyclones. They depend entirely, after their formation, on the amount of moisture that is carried to their support by the inblowing winds.

The vapor contained in the warm air which feeds the central column is condensed and the heat which was utilized in evaporating moisture when condensation takes place, again becomes sensible heat, thus adding a new factor in promoting storm energy. Several of these depressions may develop and linger for days without sufficient power for active movement and gradually drift together, when a new lease of life is given and they become suddenly energetic.

Irregular Movement of Storms.—The most difficult problem in the study of forecasting is to determine the movement of the low-pressure or storm centre. On nearly all the daily weather maps will be found one or more areas of low pressure and high pressure. The centres of the strongest of these areas in most cases are well defined and occur within a limited distance of each

other and have a tendency to affect the general course, condition and movement of each other. The surrounding weaker depressions, if to the east of the stronger storms have an influence in forming a path for the latter; for all storms, like a current of electricity will follow the path of the least atmospheric resistance. On the other hand, should an area of high-pressure linger in front of an area of low-pressure, although the latter may be the stronger, it would retard its movement, probably alter its course or may increase its rotary velocity at the point of obstruction.

Combinations of Storms.—Many combinations of low-area storms are formed by the affinity of one for the other; often two weak depressions are drawn together and form an energetic storm.

The relationship of one low pressure for another and the combinations they are likely to form, either by force of pressure from existing high-pressure areas or of natural affinity, must not be overlooked in making a forecast of the weather for any place. Next in point of consideration is the general contour of the country over which the storm is likely to pass. The influence of mountains or waterways on storm movement is a very important factor in retarding or promoting storm-energy.

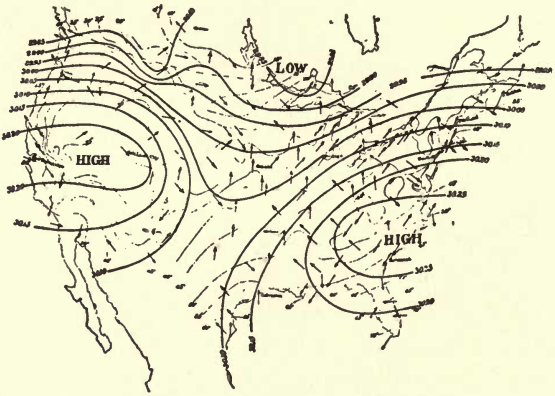
Not infrequently in encountering and passing over a mountain range storms lose their identity, in so far as their force and outline is concerned, in passing from the west to the east side of even the lowest mountains; at other times they are hardly affected; it depends entirely upon whether the body of the storm pertains mostly to the lower or upper air currents. This may be partly determined by a knowledge of the upper (cirrus) clouds, of the direction, force and time they have been blowing from a westerly direction in connection with the same conditions of the lower clouds from an easterly direction. If for a period of twenty-four hours, it is evident that the storm is influenced by the upper currents; if but a few hours, it may be considered a storm governed principally by the lower air currents. Weak depressions are greatly strengthened in passing over large bodies of water. When there is no outside influence brought to bear on the movement of a storm, it is safe to assume that the centre will follow the usual course to the eastward.

When an area of high pressure is to the north or east of a low-pressure centre, the latter is likely to move slower than when an area of high pressure is to the west, south or southeast; in which case the

low-pressure centre has an increased progressive movement.

It is found that when one storm follows closely behind another the course and movement of the one in front is somewhat deflected and weakened.

Dividing Line Between Area of Low and High-Pressure.—The dividing line between low-pressure and high-pressure areas is 30.00 inches; the strength or weakness of these areas may be rated to the reading of the pressure above or below the dividing line.



Well defined areas of High and Low pressure.

To Determine Strength of Wind.—The strength of the wind, as explained in preceding

chapters, will be obtained from the pressure gradients, that is, the number and distance apart of the barometer lines drawn around an area of low pressure or high pressure, and considering the rate of fall of pressure which has taken place and that which is likely to occur from the rate of the storm's movement, the area covered and the contour of the country. The steepest gradients are usually found on the northeast and northwest sides of a storm-centre.

Speed of Winter and Summer Storms.—Winter storms are more frequent and travel faster than summer storms; their average velocity is from 25 to 35 miles an hour and their rotary motion from 30 to 70 miles an hour. Summer storms travel from 20 to 26 miles an hour and their rotary motion ranges from 30 to 50 miles an hour, except West Indian hurricanes in which the progressive motion over the land is from 20 to 30 miles an hour and over the sea from 15 to 25 miles an hour, while the rotary motion is much greater over the ocean than over the land, frequently reaching 100 miles an hour over the ocean, but rarely exceeding 50 miles an hour over the land.

The faster moving storms are less liable to be drawn or deflected from their course and in con-

sequence much more accurate predictions as to the movement of the storm centre can be made.

The winter months have very violent storms, which occupy at times the entire country east of the Rocky Mountains; the attending features are great and rapid changes of temperature and pressure, heavy rain or snow, high winds and cold waves.

In the summer months the storms are confined principally to the northern part of the country, except those coming up from the tropics; the temperature is high and devoid of very great or sudden changes, the pressure slow in its changes, but usually above the average and the wind velocity generally light. Exception to these general conditions apply only in case of severe storm movement.

Storms of Autumn.—During autumn, the cool nights and mornings give a crispness to the air, which leads to greater definition in the outline of areas of high and low pressure.

The dry air attending these areas at this season make the forecasting of storms a simple matter, as there is usually not enough precipitation to make it the ruling factor, and the temperature lines should be closely studied to detect sudden changes in movement of the storm centres, which may produce local showers, due principally to such changes.

Storms of Spring.—In the spring the change from cold to increasing warmth takes place, showers occur at frequent intervals and there is an uncertain and listless movement to air circulation; storms after starting have a hesitancy about proceeding and frequently break up and dissipate when least expected.

During this season it is quite difficult to forecast with any degree of certainty, so the layman need not be discouraged if he finds his predictions not up to his expectations.

Local Weather Conditions.—In making forecasts from the weather map it must be borne in mind that local weather conditions play a very important part in modifying or aggravating the general conditions as they appear on the map; so by applying the local outlook to that of the general condition he will find his percentage of forecast work greatly improved. For instance, note the direction of the wind, the direction, kind and amount of clouds, and if a barometer is at hand note the rise or fall and give each its proper weight according to the force and character of the movement of any area of high or low pressure on the map which is likely to bring about any change of existing conditions.

Comparison of Maps.—In making forecasts from the weather map, it is essential that comparisons be made of the progress of areas of high and low pressure, as shown by the isobars or barometer lines from day to day, noting the increase and decrease of pressure, the distance traveled by the storm centre and the direction. Unless there is a marked decrease of pressure at the storm centre it is safer to predict a decrease of force than an increase, and if a storm is showing greater force than the average it is also safer to predict a diminishing rather than a steady or increase of force. In all cases, exceptional conditions must prevail to cause storm velocity above the average.

It is well understood that the atmosphere is con-

Isobars connecting places of equal atmospheric pressure and showing daily change.

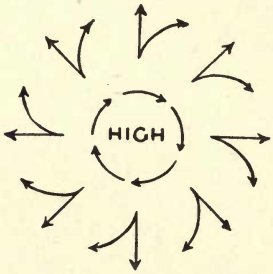
Isothermal lines connecting places of equal temperature and showing daily change.

stantly pushing from the regions of higher to those of lower pressure.

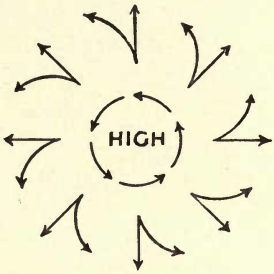
This air movement, modified by friction of the earth, inertia, the rotation of the earth and local obstructions, causes local winds as distinguished from the general winds in any section, the latter being primarily dependent upon the existence and position of areas of high and low pressure, which are governed largely if not entirely by the earth's axial rotation.

Deflection of Wind.—If the earth did not rotate upon its axis, the winds would blow uniformly in straight lines outward from the centre of every area of high pressure towards the place of lowest pressure. In the northern hemisphere, within the

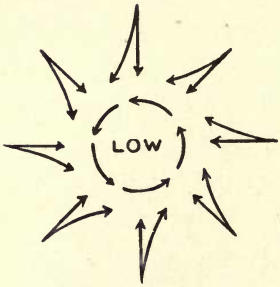
bounds of an area of high pressure, the winds not only blow away (outward) from the centre, but they are deflected towards the right. It is also the fact that the winds blowing (inward) towards the low-pressure centre are deflected towards the right.



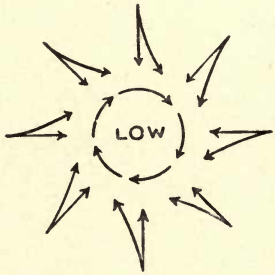
Deflection of wind
Northern Hemisphere.



Deflection of wind
Southern Hemisphere.



Deflection of wind
Northern Hemisphere.



Deflection of wind
Southern Hemisphere.

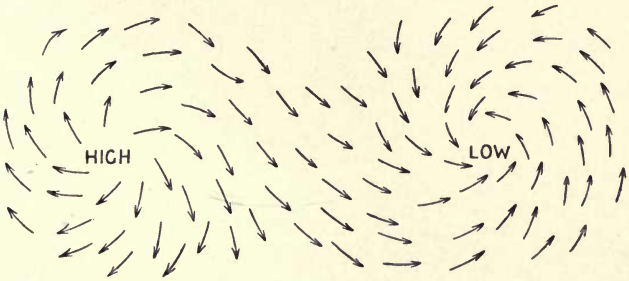
This movement, so clearly set forth by the late Prof. Wm. Ferrel, arises from the influence of the

earth's daily rotation, which causes everything on its surface to be deflected slightly to the right in the northern hemisphere and to the left in the southern hemisphere.

Direction of Wind Prevailing.

The observer being :	*LOW Pressure.*	*HIGH Pressure.*
On the N. side	N. and E.	S. and *W.*
" " N. W. "	N. W. and N. E.	S. E. and S. W.
" " W. "	W. and N.	E. and S.
" " S. W. "	S. W. and N. W.	N. E. and S. E.
" " S. "	S. and W.	N. and E.
" " S. E. "	S. E. and S. W.	N. W. and N. E.
" " E. "	E. and S.	W. and N.
" " N. E. "	N. E. and S. E.	S. W. and N. W.

The deflection of the winds is not in positive lines; while that deflection is observed, it is in conformity to the shape of the low or high-pressure areas, some of which are almost circular, but the



Circulation of wind out of an area of High pressure into an area of Low.

majority are oblong. This deflection towards the right, small as it is at the initial movement of a storm, increases with the diameter of the storm by cumulative force and seems to be the ruling element in causing low-pressure storms to have a rotary motion from right to left or an opposite movement to the direction of travel of the hands of a watch.

Surface Influence on Storms.—The forecaster will find that the surface of the earth has a greater influence upon stronger than upon weaker winds, and thus does more to retard their general motion, consequently, in severe storms on land the wind will be more directly towards the centre of disturbance than in oceanic storms, where there is less resistance and the spiral motion covers a wider area and is more pronounced.

Notes on Storm Action.—In severe storms, where the barometer lines are crowded close together, the storm will show a very material weakening when the lines near the storm centre begin to separate; it will then be safe to predict diminishing wind velocities.

Whenever an area of low pressure has been in existence for 24 hours and its path has been towards the northeast, its rate of speed for the first 24 hours will be increased about one-third for the succeeding

24 hours. When its path is to the southeast, it may be safely assumed that its rate of travel will not be increased, but most likely diminished, until it reaches a turning point to the northeast, when its rate of travel will increase. It frequently happens that after turning to the northeast the pressure at the storm centre diminishes, which creates an additional force in wind velocity.

Whenever an area of low pressure is moving from the west, rain will not begin to fall at any place to the east until the direction of the winds changes and blows in conformity to the wind direction under the storm's influence.

In the Atlantic states the rain usually begins with an easterly or northeasterly wind when the storm centre is approaching, and in the central and western states, with southeasterly or southerly winds.

When the winds along the Gulf or Atlantic coast have persistently blown on shore for twenty-four hours, it is good evidence that rain will fall within the next twenty-four hours.

Rain is most likely whenever the centre of high pressure passes to the northeast of a place which comes within the range of northerly or northeasterly winds thrown off from its centre, especially along the Atlantic coast.

Rain also falls quite frequently in advance of an area of high pressure, due to changes of temperature.

When there is an absence of any definite storm centre and the pressure over the country is normal or slightly above or below, the indications are that the conditions which exist over the central states will drift slowly into the Atlantic states.

For local neighborhoods, the absence of any barometric change indicates a continuance of existing conditions for that place.

In front and to the southeast of an area of low pressure the temperature is high and above that for the season, while in rear on the west and northwest sides there is a falling temperature. If the storm is followed by an area of unusual high pressure, the fall will be sudden and great and high winds from the northwest will ensue. In which case, it will be found that the temperature lines will be crowded closely together.

The high winds in front of an area of high pressure are very pronounced on the southeast side, are very noticeable in the lake regions and along the Atlantic coast, when storms are in these districts.

Rainfall in Advance of Storm Centre.—The rain attending the movement of storms falls from 200 to 500 miles in advance of the centre;

except in tropical storms, where the rainfall greatly exceeds that of the general land storms, and falls not more than 200 miles in advance of the storm centre.

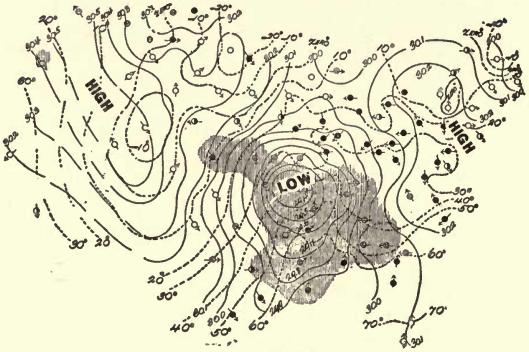
Amount of Rain.—The amount of rain that will fall in any low pressure storm cannot be estimated. It is known that storms from the Gulf of Mexico produce the greatest rainfall, which is principally deposited over the states bordering the Gulf and south Atlantic Ocean.

Low pressures that make their appearance in the northwest and move to the eastward are attended by little or no rainfall until they come within range of the lake regions; they more frequently have light rain in rear of the centre if at all.

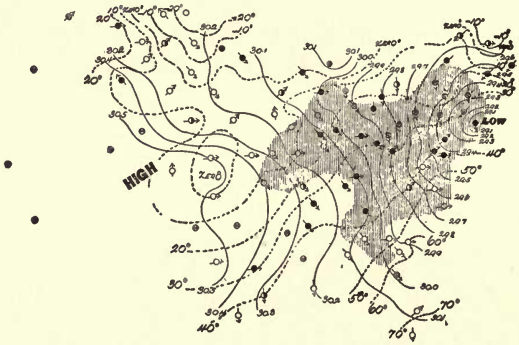
It is a general rule that when the pressure to the west of any given place is rising, clearing weather will soon set in.

If a storm is moving along a path to the east or northeast and it is found that the rainfall in its front is deficient, it will either change its course or dissipate.

A storm progressing from the west, for instance, necessarily produces different conditions, according to the section of country. In Colorado, northern Texas or New Mexico, a storm will have dry winds



No. 1. Outline of daily weather map showing storm centre in Mississippi Valley. Extent of rainfall shown by dark area.



No. 2. Twenty-four hours later shows storm centre to have passed from Mississippi Valley to lower New England Coast.

on the southern quadrant; as it moves into the Mississippi valley there is still a comparative dryness; this, however, changes when the storm

centre is located on the New England coast where the winds are very moist; so, in making predictions for the different sides of a storm area, the immediate country, its relative dryness and moisture-giving qualities must be given consideration.

Fluctuations of the Barometer.—The fluctuations of the barometer are greater in the northern than in the southern half of the country.

In the movement of the most severe storms the northern section moves faster than the southern, causing clear weather to first appear on the northwest quadrant.

Movement of Storm Centre.—If the storm centre moves to the north, the wind will shift around from the northeast to the east, south, southwest to northwest. If the centre passes to the south, the wind will back from the northeast to the north and northwest.

Temperature Lines.—The temperature lines on the weather map afford the best means of predicting severe or sudden local storms for the various sections of the country.

Tornado and Thunder-Storm Conditions.

Tornadoes and Thunder-Storms form under much the same conditions and are caused by sudden

and great changes of temperature. The lines of temperature very clearly define the flow of cold and warm air towards any section of country; when they appear close together over any region and mark a difference of from 30 to 40 degrees over a short section, it is likely that severe local storms will develop in that neighborhood or slightly to the northeast of that place.

Decided temperature gradients are found on the south and southeast quadrants of general low-pressure storms, where severe local storms may be looked for.

When the lines of temperature extend from northeast to southwest colder weather will result. When they extend from northwest to southeast, warmer weather should follow.

In all general and local conditions rain is most likely in the Atlantic and Gulf states, with winds blowing on shore.

Cold Waves.

Cold Wave.—The term cold wave naturally implies colder weather than ordinarily pertains to any given place for that season of the year.

When a change of temperature from a higher to a lower point takes place and is not the result of

the ordinary daily change from one day to another and the fall is abnormal and sudden and has an extended progressive movement across the country, it is called a cold wave. In a change of this nature it is expected that the fall in temperature will be from 16 to 20 degrees, and the minimum temperature either touch the freezing point or go sufficiently near it to cause frost.

Forecasts of Cold Waves.—For the purpose of making forecasts of cold waves, an outline of their origin, first appearance, progressive movement and general features will be given.

Fully ninety per cent. of the cold waves which are felt in the United States originate in British America, where the air is dry, the land barren, and radiation takes place very rapidly. They are ushered across the northern boundary line of Montana, the Dakotas and Minnesota as the result of development and movement of an anti-cyclone or high-pressure area, where the wind is thrown off from the centre and may be likened to a mountain of cold, dry air flowing off in all directions, with a motion similar to the movement of the hands of a watch (as previously described).

Paths of Cold Waves.—There are three paths, one of which is usually taken by these areas. The

first is eastward along the northern boundary line of the United States; the second is southeast of the Rocky Mountains to about Colorado and then eastward; the third, and generally the most active and severe, is due south to Texas, thence to the eastward to the Atlantic states; the cold being greatly modified before reaching the Atlantic coast line.

It must not be assumed that every high-pressure area is attended by a cold wave, although colder weather invariably precedes their centres on the easterly and southeasterly quadrants in winter and summer, to a greater or less extent; but the fall of temperature in other seasons than winter is rarely, if ever, sufficient to be classed under the head of cold waves.

The lowest temperatures in the Middle Atlantic states are usually produced by areas of high pressure coming down from Canada over the lake regions, forcing the cold southeastward.

Crest of a Cold Wave.—The crest of a cold wave is not at the centre of an area of high pressure, but a considerable distance east or southeast of the centre; we may say that the greatest cold is felt in the front waves of cold air from the high pressure, which follow or crowd on the west or south sides of the cyclone or low-pressure area, which invari-

ably precedes the high area. The greatest and most rapid falls of temperature take place when the temperature attending the movement of the low pressure is exceptionally high. The point of most rapid change in temperature is on the northwest side of the cyclone centre.

Centre of a Cold Wave.—As the centre of a cold wave passes over a place, there is a still cold; the winds become very light and sometimes a calm prevails which may last for several days in the central states, but not so long in the Atlantic states.

When Cold Waves Move South.—Whenever an area of low pressure appears on the Gulf coast in winter, it is safe to predict a cold wave over all the interior of the central and southwestern states, especially if the low centre moves eastward to the south Atlantic coast; in which event the cold will follow over the Ohio and Tennessee valleys and possibly into Georgia and Florida. The Appalachian system of mountains forms a protection for the Atlantic states, so that during the passing of cold waves it is found that the Carolinas and Virginia have much higher temperature than Georgia and Alabama.

Why it is Colder in the South and South-

WEST THAN IN MORE NORTHERN LATITUDES.—This is due to the fact that the crest of the cold starting from the northwest southward, being drawn on by a decided low area in the Gulf of Mexico does not lose its force until it has reached into Texas and the Arkansas valley, whence it spreads eastward to Mississippi, Tennessee and Georgia. In all these states the cold is frequently found to be more intense than in southern New York and New Jersey. In passing eastward the cold becomes greatly modified.

INFLUENCE OF LOW-PRESSURE AREAS ON COLD WAVES.—The movement of a cold wave seems to be influenced entirely by the position and movement of low-pressure areas. Most of the low-pressure areas are formed in the regions east of the Rocky Mountains, and as these areas move eastward, the high area with the cold wave moves around to the west and south of the centre of the low, apparently forming a belt or half-circle of cold air on its western and southern sides.

If the low-pressure centre fails to follow the usual path, the crest of the cold wave will follow that centre, thus proving that the movement of the low-pressure centre determines the path of the greatest cold. Thus in determining the track of a cold

wave you must first find the track of the low-pressure preceding.

FREQUENCY OF COLD WAVES.—Cold waves are most frequent in January, February and March. During January in the northwest states, they occur about once in every five days, while in February and March they occur once in every seven days. There is a steady increase in their number from September to January. A few cold waves have been recorded in June and August, but none in July.

EXTENT OF COLD WAVES.—In the majority of cold waves the outer limits extend over fully one half of the country between the Rocky Mountains and Atlantic coast, and in the largest they cover all the country east of the Rocky Mountains. The extent of a cold wave depends on the low pressure preceding it and the extent of the high pressure which is throwing off the cold.

The forecaster can count on the outline of the cold wave extending to some distance to the south of the preceding storm centre.

Those which move across the northern part of the country from west to east, do not extend to the states south of the Ohio valley or the Middle Atlantic districts. Those which move directly southeast

from Montana, cover the entire country, and in this latter class it frequently happens that the cold is felt in Texas, northern Louisiana and Missouri before it reaches Minnesota and Wisconsin. Its move eastward does not begin until it has reached its southern limit. Such cold waves generally reach Florida with a considerable degree of cold.

Rate of Progress of Cold Waves.—Many of the severe cold waves have traveled from northern Montana to the coast of Texas in from 8 to 24 hours, and from Montana to the Atlantic coast the average time is from 32 to 40 hours. The most rapid-moving cold waves follow severe storms, and the more severe the storm the more severe the cold wave.

Their appearance and movement are independent of the time of day.

Change of Temperature with Change of High-Pressure Centre.—When the centre of an area of high pressure is north of a place, it is colder to the south and east, but when the centre is south of a place, it is warmer to the north and northeast.

Precipitation with Cold Waves.—It not infrequently occurs that rain or snow falls on the approach of a cold wave, due to sudden condensa-

tion; as a general rule the fall is light, but occasionally heavy rain or snow falls.

Severe cold in the Eastern or Southern States seldom lasts longer than two days before the effect of the wave becomes modified.

Frost.

Frost.—The value of accurate frost predictions is too well known to the horticulturist and farmer to be dwelt upon here. I shall simply set forth the conditions under which frost occurs and a few ideas relative to determining when frost is likely to occur and the methods employed to protect plant life.

Conditions Favorable for Frost.—Frost occurs when the vapor of the surrounding air is condensed upon vegetation or plant life, or any substance which has been cooled by the radiation of its heat causing the temperature to fall below the freezing point. Radiation begins as soon as the heat from the sun is lost.

On the passing of the centre of an area of high pressure in the spring and fall, the calm, cool nights are very favorable for frost formation.

If the night is windy or cloudy, not only will frost fail to form, but should these conditions arise after formation has set in, it will be checked and

that which had formed would most likely disappear. A covering of any material, or smoke, haze, etc., offers a good protection from frost.

Frost is more likely to form shortly after a rain than during a long dry spell, and forms very heavy on a calm, clear night which follows a rainy or foggy morning and also on clear mornings after the early part of the night has been cloudy and generally after a very hot day.

Any substance that radiates heat freely and is exposed to the outside air will be subjected to frost.

Frost may occur when the temperature a few feet above the ground is ten or fifteen degrees above the freezing point. The degree of frost depends to a considerable extent on the radiating qualities of the soil and the amount of moisture it contains; very dry soil causes very little frost.

Frost is more likely to occur in a valley than on a hilltop, as the air in the valley is generally more calm; it also forms more often near the ground than on trees or elevated substances for the same reason.

How to Foretell Frost.—When the day has been moist and warm, either with or without clouds, when the night is clear or clearing and the temperature falling, look for frost.

If an instrument is at hand for determining the dew-point and it is found falling, with a temperature within ten degrees of freezing at nightfall and the sky clear, look for frost.

Frost is to be expected when the dew-point is below 32 degrees.

Gen. A. W. Greely, formerly chief of the Weather Bureau, states that "the approach of local frost can be foretold with very considerable accuracy from the readings of properly exposed dry and wet thermometers." A safe and simple rule to follow, when the temperature is at 50 degrees or below, is to multiply the difference between the readings of the thermometers by 2.5; when the sum thus obtained is subtracted from the reading of the dry thermometer, it leaves the approximate degree to which the temperature of the air will fall the coming night, unless change of wind to a moister quarter or increase of cloudiness interferes.

Frost forms heavier between midnight and sunrise than between sunset and midnight, owing to the cold being greater after midnight.

When the night is clear and dry, radiation is as a rule not sufficient to cause much frost.

Frost occurs with a high or rising barometer and falling temperature and dew-point.

VALUE OF FROST.—The mantle of frost which covers the trees and plant life is as beneficial as it is beautiful. It performs a part in nature's work which is very important. It has a purifying quality which is exerted on atmospheric air. Its especial action is the diffusion of nitrogen by a process of filtering all the air that passes or circulates through the foliage; gathering all the nitrogenous gases, which being returned again to the soil serve as a nutriment to plant life.

WARM WAVES.

WARM WAVES.—Any exceptional or abnormal heat, where the maximum temperature ranges from 15 to 20 degrees above the average of a place and lasts for several days or more, may be termed a warm wave.

CAUSES OF WARM WAVES.—There are two causes for warm waves; in fact, the same causes apply to all months, except that an allowance must be made for the difference in the temperature between winter and summer months. The causes which would bring about a moderately warm day in winter would cause excessive warmth in summer. First, as has been previously touched upon, the movement of an area of low pressure across the country, either in

winter or summer, is attended by warmer weather on its eastern and southern sides. This feature becomes very apparent when the centre of a low-pressure area passes to the north of a place. It is then that the winds from a warmer climate to the south of the storm centre, being brought under its influence, begin to travel north and the temperature of the southern section is carried into that of the northern. This condition lasts so long as the low-pressure centre remains to the north of any given place. The greater the depth of the low-pressure centre, that is, the lower the reading of the barometer, the greater will be the inflow of warm air; and the greater the magnitude of the general low area, the longer it will be in passing and consequently the longer the period of heat.

Second.—An area of high pressure, which, as we know, produces cold waves, likewise produces warm waves, according to its relative position to a place. When the centre of an area of high pressure passes to the south of a given place, the temperature to the north will be higher at all places which come within the range of the southerly, southwesterly or southeasterly winds thrown off from its centre.

The extent and duration of heat from this source, as in the area of low pressure, depends entirely upon

the height of the barometer reading at the centre above normal (30.00 inches), the extent of the area and its duration at a given place. The low-pressure areas of summer are confined in their travels eastward, quite generally, to the northern states, their centres passing over the lake regions and out the St. Lawrence valley. The interval in their movement usually occasions a slightly lower temperature in all the middle states from the Mississippi to the Atlantic.

The Heated Terms West of the Mississippi are more severe and prolonged than in the states east of that river. This is probably due to a trough of low pressure, starting from its birthplace in the states of the southern Rocky Mountain districts and extending along the central plateau districts to the Dakotas. The permanency of this low area in these districts in summer is a problem which still awaits solution, and whether this low-area trough is produced by any local cause remains a mystery. The author has set forth a theory, that the irrigation which has taken place in the states of that section may have some effect in the formation of these low areas and the resulting drought and heated terms in those states. This view is based on the well-known laws of storms and weather science, that low-pressure areas will form in the vicinity of or move into sec-

tions where there is moisture to nourish and promote development and warm air invariably flows into atmospheric depressions of this character.

The warm waves in the states from Texas northward to the Dakotas are almost continuous; they begin in March and continue until September. They are familiarly termed "Monsoons."

Warm Waves East of the Mississippi.—The warm waves which prevail east of the Mississippi are of a transitory order; they come and go, and intervals of coolness prevail between each two separate low-pressure areas.

Track of high-Pressure Areas in Summer.—These areas are first observed, as a rule, entering the country over California; they then pass eastward over the Central Rocky Mountain states, thence southeast to the Gulf of Mexico and South Atlantic states; they occasionally move to the lake regions and out the St. Lawrence valley, in which event they afford cooler weather all south of their track. The southern movement of these high areas pertains to the summer months only.

These areas for some unknown cause, when they reach the South Atlantic coast, apparently halt in their eastward movement and linger for days at a time on that coast; during which period all the

country to the north, principally the middle Atlantic states and New England are enveloped in a warm wave.

While these high areas hold their position on the southern coast, they in no way seem to retard the movement of low-pressure areas in their eastward movement across the lake regions, and while these areas are passing the combination formed in the indraught of warm air from the south to the north is abnormal and the heat over the intermediate states is excessive. As a rule, the highest temperature of the summer in the eastern states occurs when these conditions prevail.

Points for the Forecaster.—The forecaster, to determine excessive heat waves, must watch for the occurrence of combinations of a low pressure to the north and a high pressure to the south.

During the period of the high-pressure areas on the south Atlantic coast, the weather to the north of their centres generally remains fair, except for local thunder-storms, which may occur when the temperature of the day has been excessive and the humidity comparatively low.

CHAPTER XII

CLIMATE

To determine the climate of a place, the temperature, humidity, precipitation (rain or snow), the amount of sunshine and cloudiness, the wind (velocity and direction), evaporation, and, in fact, every meteorological element,—their average, combinations, variability, hourly, daily, monthly and annual changes,—the proximity to the sea and the elevation above sea-level, must be fully considered. For that reason, it is a most difficult problem to give the exact climatic features of any place.

It is not to be assumed that, in the treatment of climatic conditions for the United States, this is anything more than a general summary of numerous documents, statistics and papers, official and unofficial, with my own experience and study, and in addition the opinions of many noted physicians who have given the question of climate for the treatment of disease very careful study. Relative to the selection of a climate for any particular ailment, the writer refrains from giving any opin-

ions except those of physicians who have given the subject attention from a medical standpoint, and not alone from the meteorological side, where the study has been in the light of weather changes only.

The climatic features of a place have a broad bearing in a commercial as well as in a physical sense.

To the farmer, the first consideration must be the climate. He would not attempt, with any hope of success, to raise oranges or peaches in the northwest, nor would he attempt to raise wheat in the southern states in place of cotton or sugar-cane.

Notwithstanding the great advantages to be derived, the subject of climate has not been given the attention it deserves, and what it has received has been in an unsystematic and spasmodic manner and principally for the benefit of some local interests; so the information herein set forth must be accepted as it is given, as a summary of the most reliable and accurate data and opinions available.

The Principal Climatic Elements are the temperature and precipitation, and of these, temperature is the more important.

The principal conditions to consider in relation to temperature are distance from the seacoast and

the equator, elevation above sea-level and prevailing winds.

Land climate is characterized by extreme changes of temperature from day to night and from summer to winter, the greatest changes generally occurring with the distance from both equator and seacoast.

Within the tropics the temperature changes are slight and there is very little difference between that of day and night, and a nearly uniform temperature prevails throughout the year. In the middle latitudes the temperature contrasts are more marked and within the arctic circle are most decided. The greatest daily range of temperature occurs where the atmosphere is abnormally dry and clear; such conditions are found along the eastern slope of the Rocky Mountains, and especially in western Texas, New Mexico and Arizona. The great daily range is due to a lack of moisture, but it is not indicative of extreme range of mean temperature from that of summer to that of winter; in Arizona, for instance, the range of the average of these seasons is about thirty-six degrees, which is less than in many places near the seacoast.

Seacoast or Oceanic Climates have the

least daily and yearly range of temperature, due to a more humid atmosphere.

When the same amount of heat is received over land and water surfaces, the land will be heated nearly twice as much as the water, for the reason that water absorbs heat much more slowly than the land and when heated retains its heat longer than the land, which accounts for the cooler weather prevailing along the seashore and over the ocean in the summer and also for the more moderate and uniform temperature during the winter.

Moisture constantly evaporated from the ocean and in turn being condensed (furnishing rain and snow) liberates the heat utilized in the process of evaporation and adds to the warmth. An excess of moisture and cloudiness in the air along the sea-coast and over the ocean, prevents the rapid loss of heat, which takes place over the interior of the country and acts as a blanket, thereby preventing rapid radiation.

Influence of Wind on Climate.—The prevailing wind has the effect of modifying a climate by the transference of warmer air to a colder region and colder air to a warmer region, and of carrying moisture from the ocean to the land. The

difference of temperature between the water and the land gives rise to a flow of wind from the latter to the former during the day and *vice versa* at night.

This interchanging of winds is more pronounced in winter than in summer.

Throughout the interior the warmer and more moist winds are from the Gulf; their influence is exerted well into the central states to the east and west of the Mississippi valley, especially during the warmer months. This section is brought under the influence of more northerly and colder winds during the winter months.

The climate of the Pacific coast is modified by oceanic winds to a greater extent than the Atlantic coast, giving a far less daily and seasonal range of temperature, but a more unequal distribution of rainfall throughout the year. All the rain falls during the colder months of the year; the warmer months are practically dry.

Selecting a Climate.—In selecting a climate for business or health, it must not be assumed that, because the mean temperature of a place is the same as that of some other section, the climates are identical. Such is seldom the case. One may have a very even climate and the other be subject

to the greatest extremes, yet both may have the same average temperature for the year.

For instance, the mean temperature line of 50 degrees for the United States passes from New York City northwest to the southern shore of Lake Erie, thence southwest over northern Ohio and Indiana to Iowa, thence due northwest to Montana, where it turns to the southwest and passes off the coast of Oregon.

Thus it will be seen that various climatic conditions are found along the path where the mean temperature is the same.

For many reasons, in locating for business or health, the elevation above sea-level should receive proper consideration. (See change of pressure and temperature according to elevation in preceding chapters.)

Range of Climate.—The range of climatic conditions in the United States is unsurpassed by that of any other country in the world; within its boundary may be found temperatures from extreme heat to extreme cold and an atmosphere varying from excessive moisture to almost absolute dryness, with modifications meeting any requirement.

Climatic Changes.—It would be next to impossible to find a climate equable in all particulars.

We may find a climate nearly uniform by changing from place to place at the different seasons. There is a most delightful climate of dry, balmy, crisp air to be found from April to September in the plateau regions of the Rocky Mountains from Colorado and Utah southward; the farther into the mountains and the farther southward the less frequent will be found the cold winds which prevail on the eastern slope of the mountains.

From personal experience I can most heartily recommend the climate of Colorado for those suffering from lung disease. In 1874, three physicians, after several examinations, pronounced me a consumptive and even stated to my relatives that my career would be short. On the strength of the report to that effect by the surgeon of the United States army, I then being in the Signal Corps, was transferred from New York to Denver, Colorado. I felt that my days were numbered, but to my surprise I began to improve almost immediately on my arrival at the new station. At the end of one year I had fully recovered and returned to New York City, where I have since enjoyed good health, without the slightest indication of a return of lung trouble.

The climate of the regions mentioned permits

one to spend most of the time out of doors, which appears to be the essential factor for effecting a cure of lung trouble.

Dry and Moist Climates.—There is considerable difference of opinion prevailing among physicians as to the most beneficial climate (dry or moist) for consumptives; but it is generally agreed that a climate devoid of sudden or great temperature changes and without high winds is beneficial. So we find patients recommended to the west or dry climate and again we find them recommended to the Carolinas, Florida, Georgia and many of the southern states, as well as to the high elevations and mountainous districts of New York, Pennsylvania, Virginia and North Carolina.

Some ten years ago there appeared an article by Dr. J. J. MacDonald in the *Northwest Magazine* who wrote at some length to prove that the people approve of a moist climate and showed by a census bulletin that nearly all the population of the United States breathe an atmosphere containing from 65 to 75 per cent. of its full capacity for moisture—that is, that the atmosphere is from two-thirds to three-fourths saturated. The number of inhabitants living in a dryer atmosphere is comparatively trifling, to those living in the more moist atmos-

phere. In the moist atmosphere we find the larger numbers scattered along the coasts of the Atlantic and Pacific Oceans and the Gulf of Mexico. This would indicate that a moist climate was not a direct cause of pulmonary trouble.

THE ACTION OF ALTITUDE CLIMATES ON DISEASE OF THE CHEST is treated in a very comprehensive and exhaustive manner by Dr. Leudet of Eaux-Bonne and translated by W. J. Herdman, M. D., and published in the *Journal de Therapeutique*, June 25, 1874; it is here given in full.

THE ACTION OF ALTITUDE CLIMATES ON DISEASES OF THE CHEST (*By Dr. Leudet of Eaux-Bonne*).—Climatic treatment of diseases of the chest is not a new thing. It has been the custom for many years to direct those who have delicate lungs and bronchi to live in the open air under determined conditions and to breathe the outdoor air for the greater part of the day. The study of mountain climate, the question of altitudes and their action, preventive or curative, upon the development, course and recovery of diseases of the respiratory tract, especially phthisis pulmonalis, is of comparatively recent date. I will not undertake here to analyze the numerous documents which meteorologists, physiologists and physicians have

written upon this subject. These contributions are of very unequal value, and are often based on meagre observations, but in the midst of theoretical arguments, vague and contradictory, there are facts well established and determined which I will take care to point out. I wish to add that my attempt will be neither learned nor critical but assumes to give only a general impression. In presenting it, I have appealed to experience and observation; I have had in mind the patient only, a patient such as I have long been familiar with whose wants are as diverse as his sufferings are many. As to the published statistics and successes I confess I have given but little attention to them. Figures in medicine have but a relative value. It is far better to weigh the facts than to count them. This question of the climate of altitudes and its action in diseases of the chest is very broad and complex. As to its breadth, it touches all branches of the science of medicine: physiology, pathology, therapeutics and hygiene; it embraces diseases of the respiratory passages, the heart and the great blood-vessels. To consider it properly would require a book, and such a book could be written only by a skilled clinician combining with a most sagacious and extensive observation of disease, the most exact meteorological

and climatological knowledge. Need I say that I have not presumed to enter upon any such task? I only study here and pretend to study only the conditions to which the phthisical and bronchitic are subjected who live in these high places. I do not undertake the solution of any problem. I propound simply these questions and discuss them, I do not solve them.

Therefore, in order that I may not wander, but arrive if possible to sound and practical conclusions, I will start out from a principle recognized and admitted by all—that neither the bronchitic nor the phthisical ought to live a confined life, both ought to respire freely the pure and living outdoor air. If the air is the *pabulum vitæ* for healthy man, far more is it for the feeble. The best climate *a priori* will be that in which the *medical day* (*journée medicale*) is the longest. That is why I place my patients in a warm climate during winter, in a temperate climate during summer. It is the common practice—no one does otherwise; it has given, it does give good results daily; we hold to it and I believe we do well. Does it follow that warmth is the chief factor to consider in choosing a climate? Have we not in the atmosphere of certain resorts special qualities other than warmth? Is there not

in their topography peculiar conditions which give to the climate of these resorts an influence and an action which are not found elsewhere? If so, what is this influence? What is this action? Before estimating and enumerating the qualities characteristic of *altitude climate* we ought to define the climate, to say at what height it commences; to differentiate it, if possible, from *mountain climate;* to show the varieties it presents according to the latitude and elevation above sea-level.

We cannot enter very fully into this subject interesting though it be. It is incontestable that an altitude of from 6,000 to 9,000 feet should differ in its physiological and pathological effects from a lower altitude—from 3,000 to 5,000 feet for example. It is no less certain that a height of 3,600 to 4,500 feet in Switzerland or the Pyrenees has an effect entirely different upon man, sick or well, than does the same elevation in another latitude, as upon one of the slopes of the Andes or of the Himalayas. But what are we seeking? The solution of, or at least light upon the therapeutics of a clinical problem—and how this problem in reality presents itself. Therefore we need not consider among *altitude climates* those of the high plateaux of Mexico and India. It is not there we send our patients.

We send them to Switzerland, and it is in the *sanatoria* established there that we cause them to live, that we wish them to live during the winter, and it is the action of these *sanatoria*, their influence good or bad, which interests us and which we ought to know. *Altitude climate* and *mountain climate* will then be synonymous for us, and it is for us to inspect with this view, particularly, the winter resorts of Switzerland. Let us consider the distinctive characters of these resorts.

In altitude climates there is what is called a *medical day*. The patient is able at Davos or at St. Moritz, as well as at Cannes and at Menton, to walk about each day during a certain number of hours, but it is not the duration of this walk in the open air which gives character, so to speak, to a mountain climate. That is determined by other qualities, by special advantages; the *rarity of the air* on one hand, its *purity*, its *dryness* and its *invariability* upon the other, are the chief factors in the beneficial action exercised upon the phthisical by the *sanatoria* of elevated plateaux. Let us examine briefly from the point of view of physiology and clinical effects the conditions surrounding the inhabitant of elevated places due to the atmosphere in the midst of which he lives. In the first place,

the *rarity* of the air. It is the first and most important factor of mountain climate. The oxygen is rarified, its tension is less. What is the result of this upon man, either well or sick? A veritable respiratory diet which desanguinates the former, while it calms and strengthens the latter. No one has given more attention than M. Jourdanet to this anemia of high places, this disoxygenation of the blood, this anoxhemia, as it is called, which is due to the diminished density of the air, and which affects not only the respiratory functions, but also the circulation and the nervous system. No one has shown better than he that this anoxhemia of elevations, which is really a chlorosis, is antagonistic to pulmonary phthisis, and that which favors one opposes the other. Chlorosis and phthisis are antagonizing diseases, which neutralize each other, one being cured by the other. If the consumptive is consumed without measure, let us abate the activity of his organic combustion and check it by chlorotic anemia by which the nutritive changes are retarded. Doing this we correct it and furnish arms for the strife. In this case what furnishes the arms? The altitude climate, the rarified air of the highlands. And by what means? By diminishing the amount of oxygen in the blood by which he is

consumed and by arresting the organic waste which is destroying him.

This is the theory. Is it true or is it false? I will not discuss it. Is it applicable to all altitude resorts? I do not believe it, but for my part whether true or false, whether the result is rightly or wrongly attributed to it, does not in the least reflect upon this as a real and genuine medical idea, the idea of antagonism in pathology and in therapeutics. At this time, and notwithstanding the promises of the laboratory, the question of *soil*, that is to say, of the *organism*, always preponderates in the therapeutical and hygienic affections of the chest, and of pulmonary phthisis in particular. In order to cure a phthisical patient, the surest means is to create in him a general and local state physiologically or pathologically contrary to the life of the virus ferment, which has seized upon and is developing in the structure of his tissues. Do we not see every day cases of lung diseases improving in vitality and growing stronger under the influence of change of climate, by a turn of fortune breaking away and escaping from pathological servitude. The specific microbe is always there, the bacilliary nidus is not destroyed, but the lesion is removed. It seems that the disease is destroyed, or at least

arrested. However ephemeral these recoveries or arrests may be, they signify something. They create a new state in the organism. They prove that there is an influence, however insignificant it may be regarded (and if we so judge it, it may be that it is because we are unable to comprehend or to appreciate its value) that is capable of giving to the phthisical a relative and momentary respite. To hinder the parasite in its growth, to impair its function, to create about it a medium which retards or checks its development, appears to me to be possible and medical. As to testing this directly, it might be attempted. Physiological experiment is, in fact a duty, and has given us the right to expect success from it, but these successes which we are always seeking have for the most part resulted only in illusions and failures. In all the attempts made up to the present time to discover a pulmonary parasiticide, genuine and efficacious, none has succeeded. The clinic has not kept pace with the facts of the laboratory. How, then, can one be preserved from a microbe which is omnipresent, which is everywhere? The immunity of latitudes is referred to in connection with germ pathology. It is said and repeated of the plateaux of the Andes or of Switzerland that the phthisical are never seen there, that

the bacillus tuberculosis is unknown there. Does it follow from this that phthisis cannot be developed in those regions? Does the absence of a disease imply that its entrance into that locality is an impossibility? Is it necessary to cite facts to the contrary? Islands and mountains which have not known contagious maladies have been ruthlessly and brutally decimated. In the name of the same microbic doctrine, have we not the right to affirm that the most healthful resorts, the inhabitants of which are exempt from all tubercular affections, may be infected. The bacillus of Koch which is not to-day in the air which we respire may be there to-morrow. It is sufficient that the patient bring it, sow it and disseminate it.

The immunity which a country affords is not found, as is seen, either in the soil or in the air. It is due only to the absence of a pathological virus. When that appears the immunity ceases. But let us not search for an atmosphere deprived of microbes. It is seeking a chimera, but let us choose a climate which arms the impoverished organism for the strife, which recuperates and fortifies it, which modifies its fluids and its tissues, which changes its conditions of morbid receptivity, which creates in it a culture medium in which microbes

and bacilli are not able to live. This brings me to the local factors of mountain climate and to their physiological and pathogenetic action in diseases of the chest. Apart from the *rarity* of the air, of which I am going to speak which is, and which remains the specific condition of altitudes, I do not see anything characteristic in the qualities of the atmosphere of mountains. Purity of the air, its dryness, its constancy, its clearness, and its freshness, which are spoken of as attributes of a high plateau are found elsewhere, on the seaboard, in valleys as well as in the mountains. They are the common qualities of which the hygienic and therapeutic value is as imperfectly defined as it is difficult to appreciate. If the air is dry and bracing in the mountains of Switzerland it is at the same latitude moist and heavy in the Pyrenees. A cloudy sky, foggy and cool, can have upon the bronchitic and consumptive as beneficial an action as a clear atmosphere, light and cool. Nothing is more variable, nothing more inconstant than the meteorology of the mountain. Nothing is less absolute than the medical indications provided from thermometric and hydrometric means. All the factors of a climate are fixed immutably upon the instruments which register them, but the patient does not

submit himself to the exterior influences like an instrument of precision. A phthisical person, indifferent to-day to a slight elevation of temperature or an intense solar radiation, will to-morrow be unpleasantly affected by the same agents and the reaction which he will manifest, instead of being salutary will be hurtful. Is there any patient more protean than a consumptive? Shall we make the tuberculous who has fever and the one who has not dwell in the same place? Should the consumptive who takes cold whenever he is exposed to the air be put side by side with the one who never takes cold whatever exposure he undergoes and whatever his lesions? A feverish consumptive is irritable, extremely sensitive, not only to variations of the atmosphere, but to a too prolonged dryness of the air, to its constant clearness. For him all irritation is dangerous, every inflammation unfortunate. Shall we associate in the same sanatorium tuberculous patients having pulmonary lesions, with scrofulous patients having ganglion enlargements? The latter, under the influence of the sharp cold air of Alpine heights, receives a stimulus which reanimates his circulation, arouses his nervous system, and prevents caseous formation, which threatens his lung with disorganization. The former ought

to seek a locality in which the sedative and soothing action allays his irritability, moderates his febrile reaction, quiets the acuteness of his bronchial phlegmasia, puts it at rest and favors its recovery. I have for a long time insisted that there are several forms of pulmonary phthisis, that there are periods of exacerbation and quiescence which in the treatment of the disease alone determine the indications, prophylactic or curative. But it is sufficient for me from a practical point of view (the only one which I am considering) to define two main divisions of phthisis, the irritable, the congestive and hæmmoagiac on one side; the mucous, the catarrhal and the suppurative on the other. Now, what is demanded of altitude resorts during the winter season? Certain conditions of temperature and certain qualities of air. But these conditions and these qualities as I have already said, exist in localities far separated. Outside of the rarity of the air, which is the characteristic factor of the atmosphere of elevated plateaux, and the action of which from a clinical point of view is yet to be determined, I do not see anything which pertains particularly to the mountain. The physiological and therapeutical effects, which we attribute to elevations, we are able to secure upon the plain. May not the influ-

ence, good or bad, which the bronchitic and the consumptive obtain by a sojourn at an elevated resort, be found in Provence, or at the seaboard, as well as in the mountain resorts of Switzerland? What is the conclusion? If the mountain, the plain, and the seaboard act upon the phthisical patient in a like favorable or unfavorable manner, if the mountain succeeds as the seaside, if the seaside fails as the mountain, the merit or fault can only be attributed to the patient himself. The consumptive is a variable person. That which is beneficial to-day is hurtful to-morrow. The most diverse medicines, the most opposite in action, do him good in their turn. We have only to cite in support of this statement the variety of weapons which our therapeutic arsenal offers us by which we can come to the aid of our patient.

But it is here especially, in the presence of this grand therapeutic agent which we call climate, that the choice is difficult and the decision weighty in consequences. Yes, the cold and piercing air of the plateau of the Engadine, the clearness of the sky and the intensity of the solar rays are well calculated to restore the organism and favor the activity of the respiratory function, but it is necessary that the consumptive be able to live in this

air, and to live in a certain manner. It is necessary that his strength permit him to take his walks and to engage in daily exercises which stimulate his blood and enrich his nutrition. At this price, a winter residence in Switzerland is for him a veritable means of combat which prevents or checks his disease. But this method, applicable to the initial periods of phthisis, not in all forms, but such as are slow and inactive, will be hurtful to the majority of confirmed tuberculous patients who are too feverish and too irritable to benefit much by an exciting climate, and one subject to hygienic perturbations. Such persons have need of climatic conditions entirely different. A policy of aggression must give way to one of protection. I have said sufficient to show the uncertainty and complexity of the question which I study. The action of altitude climates is a hygienic and therapeutic problem, which can be solved only by the clinic. That has not yet spoken. Let us await its decree. Until then let us hold our opinion in reserve.

Let us bid defiance to custom and example and meditate upon the words of Hirtz, the eminent clinician, the lamented professor of our school at Strasbourg; words written in 1874, but as true today as then:

"As to the residence of patients upon mountain heights in winter our opinion at present is not very positive. This extreme practice is evidently a reaction from the abuse of the opposite practice which never found a climate warm enough, nor a winter mild enough, nor a temperature equable enough to shelter the invalid. This reaction if it should become a custom will conduce to disastrous results and will abridge, in more than one instance, by an intercurrent pleuro-pneumonia, a life which otherwise would be prolonged.

"But, conducted with good sense, and in the light of physiological pathology, and directed by exact clinical observation it will admit of precise indications for the choice of those who would be encouraged by such attempts"—(*Journal de Therapeutique*, June 25th, 1874).

Here I should close. What can I add after so profound and correct a judgment has been pronounced? I ought, however, to embrace in some precise and condensed propositions the thoughts that have been presented.

1st. Altitude climates have, upon affections of the chest an incontestible action, all powerful as a preventive, relative or of no account as a curative;

2d. When the disease is infectious or virulent

they modify the *soil* but do not affect the *seed*, they do destroy the *ferment*;

3d. The *immunity* they furnish in presence of pathogenic germs is neither real nor absolute; it is accidental and contingent.

4th. Their verifying and tonic action seems dependent upon multiple conditions of which some, as freshness and purity of the air, its transparency and its immobility, have an incontestable importance and only one of which, *rarefaction of the air*, is really specific.

5th. Those persons possessing sensitive bronchi and lungs—those threatened with and predisposed to consumption derive a decided benefit from a prolonged sojourn on high plateaux upon the sole condition of the tissue not being irritable and having been methodically brought to live under the conditions of mountain climate.

6th. The confirmed tuberculous ought to pass the winter with advantage in the Swiss *sanatoria*, provided they do not suffer from congestion or hæmoptysis, and provided they are strong enough to engage each day in such gymnastic exercises as a stimulating and quickening air demands.

THE ATMOSPHERE AND PULMONARY HÆMORRHAGE.—The following views were expressed by

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

Dr. Roland G. Curtin at the Boston meeting of the American Climatological Association as to the effect of atmospheric influences on hæmoptysis:

1. Preventive and Curative Elements.—*Rarefied air* arrests the ulceration or other diseased processes and lowers the arterial tension. This greatly overbalances the unfavorable tendency of increased heart action and loss of support to the lungs from diminished air pressure. *Cold air* contracts the tissues and blood-vessels, thus preventing a flow of blood when such tendency exists; its general invigorating effects are beneficial. *Dry air* desiccates the pulmonary tissues, decreases the fluidity of the blood, and blocks up the blood-vessels—all favoring the arrest and prevention of bleeding. *Aseptic air* favors repair and cure of lung disease, and kills or dwarfs the action of the disease germ. *Outdoor life*, when not associated with too much exposure, exertion or fatigue, is beneficial.

2. Causative Elements.—*Sea-level air*, by its greater density, diminishes the tendency to hæmoptysis; but the increased arterial tension, and the moisture usually present in such localities, more than counterbalance the beneficial effect of the support given by the air pressure. *Salt air* hastens the breaking down process in tubercular lung dis-

ease. The effect is probably good in syphilitic lung troubles and sometimes in simple chronic inflammatory non-tuberculous lung affections. *Moist air* hastens the ulcerative process, liquifies the blood and secretions and renders the tendency to the oozing and flowing of the blood more liable. *Warm air* releases the tissues and blood-vessels, and enervates and relaxes the system at large.

Thus he concludes that each case should be carefully studied in all its phases before deciding on a change of residence. On a high mountain (say from 5,000 to 10,000 feet), a residence far removed from the seacoast is best for a patient with a tendency to hæmoptysis. At a location of this kind one would probably have not only a rarefied but also a cold, dry, aseptic air; factors which would be most beneficial. Care should be taken that the elevation of the patient should be gradual and not too rapid; otherwise the early effect of a sudden elevation might be followed by unpleasant results. A case of syphilitic phthisis will probably be benefited by sea-air, while a tubercular patient would be injured by it.

Climatic Treatment of Phthisis Pulmonalis.—The following extract from a paper read before the American Medical Association at its last

meeting, by W. L. Schenck, M. D., of Osage City, Kansas, is a fair sample of the views at present held by the thoughtful general practitioners in this country as to the therapeutic influences of the various elements of climate in the cure of pulmonary consumption.

The value of each factor as pure and dry air, equable and moderate temperature, abundant sunshine, moderate elevation, are getting to be very generally conceded.

The chief want now felt by the medical profession is a complete and unbiased record of these climatic conditions in localities that are not so remote from populous regions, but that patients in the early stages of the disease may reap their benefits without the necessity of abandoning all occupation with no opportunity to moderate the expense, otherwise but a very limited proportion of those affected with this ever prevalent disease will be able to avail themselves of the advantage that a change of climate might afford.

Professor Jaccoud, than whom we have no better authority, in his work on "The Curability and Therapeutics of Phthisis," considers the disease curable in all its stages—not all cases, but curable as are other diseases. In all treatments he relies

largely upon the influence of climate, adapting its conditions to the individual case. Notwithstanding Jaccoud's dictum, there are widely differing opinions as to which is the best climate; thus, we find the balmy air of sea-surrounded Orotava praised, the soft warm breezes of St. Augustine, Fla., the fragrant odors and almost tropical warmth of the Louisiana pine-belt, the high cold climate of Colorado, and the damp and chilly atmosphere of lake-girt Michigan. As these widely differing opinions seem but the varied notes of "Home, Sweet Home," we must consider principles and statistics.

Before we can give intelligent advice to invalids we must understand the various elements entering into and producing what we call climate, and their impress upon life, as thoroughly as the etiology and pathology of disease. Webster defines climate as "the condition of a place in relation to the various meteorological conditions, as temperature, moisture, etc."

Climates are mainly created and influenced by latitude, topography, superficial strata and the presence or absence of large bodies of water, and are the aggregate of atmospheric conditions of particular localities at specified seasons. The chief elements to be considered in climatic treatment are:

1, purity; 2, rarefaction, as produced by altitude; 3, dryness; 4, temperature; 5, variability; 6, sunlight; 7, electricity; 8, atmospheric motion. The first and second elements are chiefly influenced by altitude, the others by latitude, configuration, and porosity of the surface and relation to bodies of water.

Dr. Dennison advocates the "dry, cool, rarefied, stimulating and sunny atmosphere of Colorado," because, among other reasons, "cold stimulates and heat depresses." Is not this as fallacious as the Thompsonian dogma, "heat is life, and cold is death"? A limb mutilated beyond hope of recovery is restored through the stimulus of hot water dressings, and a frightful post-partum hæmorrhage is arrested by the stimulus of hot intra-uterine injections. "*In media tutissimus ibis*" must be one rule in selecting temperature for the consumptive. An atmosphere that stimulates through altitude, and yet wooes to outdoor life, is most favorable for the prevention and cure of phthisis. It is not the heat or the cold that tends to cure in phthisis. Robust health may endure an inhospitable climate, but such a climate does not produce robust health in those of marked tuberculous heredity; while in damp air, cold or warm, containing

less oxygen than dry air, which is absorbed less readily from the moist membrane, there is diminished oxidation of the blood engorgement of central organs. Dr. Dennison thinks nightly chilling and sometimes freezing renders the atmosphere "inimical to germ life." We don't know so much about the health of the germ, but we know such conditions are inimical to human health.

Whether from the direct effect of abstraction of moisture from the pulmonary tissue, or the consequent control of pulmonary temperature, or other cause, a dry atmosphere is essential to climatic treatment. Change in temperature, when the range is not too wide, may not injure vigorous life; but the alternations of temperature, the hot days and cold nights, so common in all damp climates, leads to engorgement of central organs—spleen, liver, kidneys, lungs,—to periodic and congestive fevers, to lowered vitality and to consumption, wherever the predisposition exists. Damp, hot days and damp, cold nights produce directly opposite results to dry, high altitudes, where external tissues are hyperæmic and internal organs anæmic. Cold condenses the atmosphere. In cold weather, at low altitudes, the full use of the pulmonary tissue and circulation is not required, and there is tendency to

atony and the tubercle cell. In simply cold climates, of whatever altitude, sudden and extreme changes fall heavily upon the exposed lungs, and such changes cannot be avoided. Much of the time must necessarily be spent in artificially heated rooms, too often illy ventilated, between which and the outdoor air there is a difference of many degrees. It goes for the saying that the advantage of climate is the climate and not the heated air of the living room. A climate that permits and invites outdoor life is a necessity to satisfactory climatic treatment. Cold and rain confine the patient indoors; a warm, moist air tempts to indolence, and a hot, dry air leads to idleness and the shade, while a high, dry air of vernal temperature stimulates to outdoor life and exercise, and so fills all the conditions of climatic treatment.

Climatic treatment is based upon more rational grounds than the destruction of germs. In an atmosphere rarefied by altitude the pressure upon the surface of the body is diminished and the vessels of the periphery are turgescent, while the viscera are comparatively anæmic. The pulmonary circulation freed from hyperæmia, congestion and obstruction, tendency to hæmorrhage is prevented or relieved, respiration is full and free, the cerebro-

spinal functions are more active, the great central glands relieved of remora and congestion, effete matter is more thoroughly removed, the appetite, digestion and nutrition are improved, the desire and capacity for exercise increased, and we begin to feel

> "The wheels are just as strong as the thills,
> And the floor just as strong as the sills,
> And the panels just as strong as the floor,
> And the whippletree neither less nor more,
> And the back crossbar as strong as the fore,
> And the spring and axle and hub encore."

The "hardy mountaineer," with his physical and mental activity, does not owe all his growth to mountain scenery, but illustrates the beneficial effects of altitude. The rarefied atmosphere and the relative anæmia of the lungs, other things being equal, demands and permits full drafts of air, while the brain and all the great vital organs, permitting an unobstructed circulation of the vital current, tissue degradation and deterioration are prevented or relieved.

Professor Jaccoud says: "Mountainous climates at the height of from 4,900 to 6,200 feet have in reality a double effect: Firstly, a general one, by which the constitution is restored to a healthy con-

dition; secondly, a local one, by which the activity of respiration is increased to a maximum, while the lung is protected from the effect of congestion and hyperæmia. Climates which, on account of their more northern latitude, present analogous conditions of temperature at a lower altitude, produce the same tonic effect. They have not, however, the same mechanical influence upon the lungs, this being entirely due to barometric pressure. Climates with moderate pressure are wanting in the mechanical action of rarefied atmosphere, and there is insufficient tonic and fortifying effect; nor do they possess that special purifying effect peculiar to high latitudes; they therefore fulfil only secondary indications—secondary in themselves, or at the time when they occur. While such climates have no curative effects on the disease and are not preventive of fresh tubercle, they may, on account of having a temperate, or warm, fresh temperature in winter, act favorably upon any preexisting bronchitis or pulmonary catarrh. Confinement within doors is unnecessary, and much of the time may be spent in the open air without danger of provoking bronchitis or pneumonia, which would not be the case in a more rigorous climate, or one having greater variability of temperature. It is thus seen

that climates of the second-class, while of an undoubted value in the treatment of phthisis, are only of secondary importance."

Altitude in any latitude that does not permit to the consumptive outdoor life loses much of its advantage. If we can find a locality with a comparatively dry atmosphere which at 4,000, 6,000, 8,000 or 10,000 feet will permit patients to live largely out-of-doors, they will at the same time get the benefit of barometric pressure, climate and healthful exercise. Though not a resident of New Mexico, its barometric pressure will range from 4,000 to 10,000 feet with a climate that will permit and stimulate outdoor exercise, with which its hygrometric conditions will rarely interfere.

The damp, cold climate of lake-encircled Michigan is excellent for consumption, but bad for the consumptive, and its statistics prove what science teaches. According to the census reports of 1870 and 1880, it has a higher death-rate from phthisis than any other inland state in the Union. Of its deaths in 1870, 16.4 were from phthisis, and in 1880, 13.2.

In the states lying upon and near either ocean in the northern portion of the United States, notwithstanding their altitude we have the highest death, rate from phthisis, the acme being reached in Maine,

where, in 1870, 25.6 of the deaths were from consumption, and in 1880, 19.2; in New Hampshire they were 22.2 in 1870, and 15.7 in 1880; in Massachusetts, 19.9 and 15.7; in Connecticut, 17.9 and 19.2; in Rhode Island, 20.1 and 14.7; in California, 13.8 and 15.6; in Oregon, 18.2 and 12.1.

The warm, damp air of the Gulf States, with their lower altitude and higher temperature, give much more favorable statistics than those somewhat similarly situated as to moisture, but with more rigorous climates. Thus, the percentage of deaths from phthisis, as shown by the census of 1870 and 1880, were 5.7 and 8.0 in Georgia; 6.4 and 8.0 in Alabama; 7.0 and 9.0 in Mississippi; 7.0 and 8.2 in Florida, and 7.7 and 8.2 in Louisiana.

Colorado and Nebraska, so highly lauded for the influence of their climate on the consumptive, show by the same census a slightly larger proportion of deaths from phthisis than the low-lying but warm states on the Gulf of Mexico. Thus, in Colorado 8.5 and 8.2 were from phthisis, and in Nebraska, 8.7 and 7.0. In New Mexico the deaths from phthisis are given in 1870 as 3.8, and in 1880, 2.5, and in Arizona, 4.0 and 6.9, and this where the native population suffer largely from a specific disease that tends to a type of phthisis.

From the view we have taken of the etiology and pathology of phthisis, as well as from statistics, we conclude that a sanitarium for consumptives in New Mexico, away from the hot springs, with their excess of moisture, upon an arroyo of 4,000 or 5,000 feet above the sea, with cottages extending up the mesa to 10,000 feet, permitting patients to be moved up or down, as their condition permits or requires, will secure to the consumptive all possible climatic advantages and make for them the most perfect retreat known to any country or clime.

Yet we must remember that in all climatic treatment we must "temper the wind to the shorn lamb." In the flat and narrow chest, in tuberculous deposit confined to the apex, or yet more extensive if the purulent stage has not been reached, altitude, high, dry and equable, with a climate that encourages outdoor life, is positively preventive and curative, not in a day or a year, but continued until the cure is complete. When caseation and softening are more extended, a mild, dry and pure atmosphere is required, such as may be found in the lower altitudes of New Mexico and in the Carolinas, Tennessee and Georgia. When the tuberculous deposit is extensive, expectoration copious, hectic marked and emaciation extreme, the probabilities of cure are so

small that the pleasures of home, where love may make the dying bed "soft as downy pillows are" should not be exchanged for an arduous journey to end in a final struggle away from the comforts and consolations of home and friends.

Mountain and Sea Air.—Highly nervous persons, the victims of hypochondria, those suffering from excessive brain work—above all, those in whom these conditions are found in conjunction—should not, as a general rule, be advised to try the seaside. A quiet inland locality, or some mountainous spot of moderate elevation, will be found to suit their cases better. The monotonous aspect of the sea and the ceaseless beat of its waves are mentally depressing, while the highly-strung neurotic patient is irritated instead of braced by the stimulating effects of the sea-air. Those who are just recovering from a serious illness, such as pneumonia or typhoid fever, should not be sent prematurely to the seaside, as an accession of febrile symptoms is frequently the untoward result. An inland locality is more suitable during early convalescence; but, later on, nothing conduces more to complete cure than a resort to the seaside. The marvelously restorative effects of sea air in cases of slight general debility, in persons of strumous habit, and in those

with family predisposition to phthisis, are well understood, and must not be regarded as being in any degree impugned by the opinions expressed in the present article.—*British Medical Journal.*

ALTITUDE AND HAY FEVER.—In an article by Dr. W. J. Herdman, he points to the fact that elevated resorts, no matter in what part of the country they are located, have, as a rule, gained a reputation for a curative and prophylactic influence upon hay-fever. Thus the White Mountains, the Adirondacks, Roan Mountain, and many places in elevated regions beyond the Mississippi have well founded claims to immunity from those conditions which occasion this periodic disorder at this season.

The reasons assigned for the blessed relief experienced by the afflicted who flee to the mountains in midsummer to escape a recurrence of this distressing malady are, the purity of the atmosphere from all irritating particles, either organic or inorganic, which in contact with oversensitive mucous membranes of the nose, throat, or bronchi might excite inflammation, and the tonic effects of a cooler, dryer atmosphere in increasing the body resistance to such irritants.

In considering the comparative value of the various factors which make up the conditions

resulting in benefit to the patient who finds relief from this disorder at one of the many mountain resorts, it has seemed to us that writers have uniformly failed to attach to the effects of altitude alone the importance which it deserves.

It is highly probable that the direct action of altitude upon the patient is attended by as much, if not more benefit in warding off an attack of hay fever than the freedom it insures from irritating particles.

The majority of mankind in the midst of conditions believed to be causative of this disease are not victims of it. This must be due to some capacity for resistance in them that is not possessed by their less fortunate neighbors. The physiological state and action of their air passages differ in some manner from those who are subject to the disease. A greater irritability, a proneness to catarrhal congestion and inflammation in the mucous membranes lining the air-passages constitutes this difference. The seat of this susceptibility may be primarily in the nervous system—a vaso-motor instability—or it may be due to some local change in the membranes themselves. Whichever may be the starting point for the phenomena these are marked by an in-

creased blood flow to the parts affected and the result is congestion and exudation. The many disagreeable symptoms of which these sufferers complain are the immediate consequence of this increased and abnormal vascularity.

Repeated attacks of catarrhal inflammation weaken the resistance of the membranes involved, lowering their tone, and the nerves distributed to the part become so oversensitive that they respond excessively to the slightest stimulus and in consequence a passive congestion becomes a constant condition of these membranes. Any cause, therefore, that will operate to prevent or retard this local congestion will be a very important factor in effecting a cure. A considerable altitude has just this effect. The decreased atmospheric pressure acts upon the vascular system as a constant derivative. It dilates the cutaneous blood-vessels and has the effect of a continuous and decided vasomotor counter-irritant preventing, thereby, the conditions favorable to a local congestion of the mucous membranes of the upper air passages.

That the subsidence of congestion is an important and real factor among the curative influences of elevated resorts upon this malady, is demonstrated and confirmed by witnessing the relief afforded in

acute attacks of this disease by medicinal and physiological means which have a similar effect in equalizing the circulation, although with much less constancy than when brought about by the influence of altitude.

Aconite, belladonna, the bromides and the many astringent and sedative sprays and douches that are advised in this disorder are of service in diminishing congestion and allaying its consequent ill effects, while active muscular exercise, especially with the arms, at the commencement of an acute attack of hay-fever coryza, will, if it does not wholly arrest the attack, greatly mitigate its severity, diminishing the distressing tightness in the nostrils, throat and chest and checking the secretion of mucous.

What we can thus do temporarily and fitfully by the application of medicinal agents and purposive muscular effort, is done constantly and effectively by the diminished atmospheric pressure of altitude, and hence we find in elevated resorts an additional factor in the cure of this disorder which is not possessed by any low-land resort, no matter how favorably it may be located for securing purity of atmosphere. Purity of atmosphere might alone prove sufficient but when this can be secured to-

gether with the beneficial effects of altitude it offers increased advantages.

The atmosphere at an elevation above 3,000 feet has been found by several experimenters to be comparatively free from pollen no matter what the direction of the wind, while a change of wind at a lower level, a land-breeze at a seaside or lake resort might become laden with such plant products and occasion a sudden outbreak of the disorder among its residents, as has frequently happened in such places. But even should the irritating particles be found in greater abundance in the atmosphere of mountains, the altitude, for the reasons above stated render the patient much less susceptible to their peculiar influence. But it should be noticed in this connection that the elevation chosen with a view of securing immunity from hay-fever should be a moderate and not extremely high altitude, nor one in which the body is subjected to prolonged isolation. Such conditions are known to increase nervous irritability and in that manner might operate to counteract the good that is sought. An altitude between three thousand and six thousand feet, and in a locality not too free from moisture, and with an equable diurnal temperature would seem the ideal resort for those

afflicted with a tendency to hay-fever. Frequent precipitation of moisture is itself of service in cleansing the atmosphere while a moderate amount of moisture in the atmosphere also favors electric conductivity and is sedative in its influence upon the nervous system.

CHAPTER XIII

HOW TO FORETELL WEATHER CHANGES BY THE USE OF THE BAROMETER AND LOCAL ATMOSPHERIC CONDITIONS.

To determine weather changes by local atmospheric conditions alone, one must take into consideration the direction of the wind, the direction, kind and movement of the upper and lower clouds, and the condition of the sky at sunrise and sunset. One may not be able to note all these facts; each one, however, has its significance and materially assists in the solution of this daily problem; but any of them singly are of value.

In the application of the following rules it must not be considered that they are infallible, for with the aid of all the scientific observations of the Weather Bureau, with storms and all atmospheric phenomena completely charted, the forecasts are not as accurate as could be desired; nevertheless a fair estimate of weather changes should be made from the local conditions.

It has been demonstrated on many occasions, that

local conditions when carefully considered have been the means of making successful predictions, when the general conditions as they existed on the weather map for the time would have been the cause (if followed) of serious failures.

The mariner and farmer rely solely on natural conditions to foretell weather changes; the former in many cases has, in addition, the use of a barometer; it is seldom, however, that a barometer is to be found in a farmhouse, the farmer trusting exclusively in the appearance of the sky. The mariner and farmer are able to foretell coming changes remarkably well, but with the additional knowledge herein given their predictions should be greatly improved.

The barometer, being most sensitive, is the first to indicate any atmospheric change and frequently many hours before there is any other indication.

A storm may be in the Mississippi valley; the barometer on the Atlantic coast would ofttimes mark its approach before the winds or clouds would give evidence of its coming. Then we may say that the barometer is the pulse of the atmosphere.

The change which takes place in weather conditions will be more rapid on the clearing away of a storm, than on its approach. When the wind is

east or northeast and the barometer has been falling for some time, there may be a slight rise, which would indicate the passing of the storm centre over your section and then a slight fall, followed by a rapid rise and a shifting of the wind from an easterly to a southerly, finally to a westerly and northwesterly quarter and clearing, cooler weather quickly resulting. This movement takes place when the storm centre passes over your section or to the north of you; should the centre pass to the south of you, the wind would back around to the north and northwest, and the resulting conditions would be the same as in the shifting by the south point.

On the approach of the storm, you find the wind blowing from the southwest or south and gradually backing to the east and northeast; it takes some time before the wind increases in force or the rain or snow begins to fall; it may be from six to twenty-four hours before the storm conditions appear, but it will be observed that in the upper sky the fine, filmy, cirrus clouds are beginning to form and are moving from the west or southwest or out from the storm centre, and in a few hours the lower clouds and surface winds will be found to be moving from an easterly to a westerly quarter.

The lower or rain-bearing clouds in all general storms will be found to move in an opposite direction to the movement of the upper clouds.

As these clouds thicken there will be a steady and rapid fall of the barometer with the wind increasing in force and blowing from the northeast, east or southeast with the storm centre close at hand and which will pass to the north of you. If the winds continue to back to a northerly or northwesterly point, without passing around by a southerly point, then the storm centre will pass to the south of you.

The average height of the barometer at sea-level is 30.00 inches. If the barometer rises steadily above its average height, the winds will shift to the west or northwest, and the air will become colder and dryer; if it is snowing or raining, clearing weather will rapidly set in.

If the barometer should suddenly rise, while it is from one to two-tenths above the average, high winds and in winter local snow-squalls and in summer local rain may be expected for a brief period only.

If there is a rapid and steady rise in the barometer, high westerly, or winds from a drying quarter may be expected; the more rapid the rise, the higher the winds.

The highest winds occur with a rapidly rising barometer. Stationary barometer indicates a continuance of existing conditions.

Falling barometer indicates warmer weather; rising barometer colder weather.

If the weather grows warmer while the barometer is high, the wind will shift to the south, from any other quarter.

If the weather becomes colder while the wind is southerly and the barometer low, expect a squall, with a sudden shifting of wind to the west or northwest and rain; or, in winter, snow.

On the Atlantic coast, when the barometer is high and the wind brisk to high east or northeast, look for rain or snow; in this instance (which is an exception to the rule), the precipitation may cease and the wind change to another direction when the barometer begins to fall, if the fall is gradual and does not go below the 30.00 inch mark.

If the wind is east or northeast and light and the barometer begins to fall steadily, rain is likely to set in, with a change of wind to the southeast.

The barometer usually falls with a southerly wind and rises with a northerly wind.

It is essential to remember that the winds from a southerly quarter are the moisture-bearing winds

and that moisture causes a reduction of atmospheric pressure and consequently falling barometer. On the other hand, the northerly winds are cold and dry, causing an increased pressure and higher barometer.

If the barometer is high, say, above 30.50, and remains steady, the wind will be light and the weather dry with a prospect of two or more days of fair weather.

If the barometer be low, registering 29.50, or thereabouts, and remain steady, the weather is likely to become wet, and light southerly winds are likely to prevail; but the longer the pressure remains low, the greater is the danger of a severe storm for that section; as storms forming in another part of the country seek the place of lowest pressure and least atmospheric resistance.

On the other hand, if there is a slight, but steady rise of barometer from its low point, before a storm sets in, the chances are favorable for a day or two, at least, of fine weather.

In the spring and fall under these conditions fogs are likely in the morning.

When the barometer begins to fall from a high point after a period of dry weather, it is quite safe to expect a period of unsettled or stormy weather,

especially in the colder months; in the warmer months showery, sultry, warmer weather results.

The barometer usually falls with a southerly wind, because the wind from the south is warm, moist and light; rain generally follows, especially if the upper clouds are from the same direction.

The barometer usually rises with a north wind, because the air from that quarter is cold, dry and heavy and fair weather follows a change to that quarter.

Southerly winds give a much longer warning of an approaching storm, than northerly winds, because southerly winds will often begin to blow at the higher elevations before they appear at the earth's surface, and may be detected in the passing of cirrus clouds or mare's tails and in very high winds a fine scud of cloud.

The warning from the north is found in the heavier clouds, which move with the surface winds.

In general and extensive storms their coming may be foretold by a slow and steady fall of the barometer, the fine cirrus clouds at a high elevation flowing from a westerly to an easterly or from a southwesterly to a northeasterly point, or out from the centre of disturbance, generally from ten to twenty-four hours before the next and more pro-

nounced indication appears, which is in the change of the surface wind to an easterly or northeasterly direction and the appearance of dark and heavy clouds in the lower air strata, moving in the same direction as the surface winds.

With an unsteady or fluctuating barometer, look for a moderate change of weather. A sudden rise in the barometer is equally likely to bring a gale of wind as is a sudden fall.

High winds almost invariably occur when the barometer begins to rise after having been very low.

The barometer may rise or fall slowly from the average without there being any perceptible atmospheric change, which may be termed the natural movement, the careful observer, however, would be able to detect a movement of such a nature from one meaning a disturbance.

Then there is a daily oscillation of the barometer, which makes it read highest at 10 A. M. and 10 P. M. and lowest at 4 A. M. and 4 P. M. These changes, however, are very slight and play no part in causing confusion in calculation of storm movement. The dominant factors of barometer changes are sufficiently pronounced to avoid confusion.

For the benefit of mariners it would be well to

state that peculiar and somewhat dissimilar characteristics are observed over the ocean to those over the land in foretelling the approach of hurricanes, which occur from July to October inclusive. For several hours, fine, filmy, cirrus clouds may be observed moving northward at a high elevation from a southerly point, which finally results in a hazy atmosphere; the sea becomes quiet and there will be a slight rise in the barometer; this latter condition may be misleading when taken in connection with a calm sea and light breeze; but the captain must ever bear in mind that, "the calm precedes the storm," which is very evident in the advance of a hurricane. The slight rise in the barometer is soon followed by a fall, dark, thickening clouds obscure the horizon and a difficulty arises in determining which is sea or sky. The wind begins to blow towards the centre of disturbance with the stiffening breeze and there is no time to be lost in preparing for safety when these conditions appear.

Thunder-storms are preceded by a gradual fall in the barometer (in most cases), which occupies several hours; again there is an abrupt fall and only a short time intervenes before the thunder-storm breaks in full force. In nearly all cases, the wind blows from the east or south for several hours

before the barometer falls or the storm forms, and the atmosphere appears dry, but close. As soon as the body of the storm reaches you, the barometer rises rapidly, the winds whip around to the west or northwest and cooler weather is at hand. Frequently the temperature drops from ten to thirty degrees. After the atmosphere regains its equilibrium the temperature will rise somewhat and the winds decrease.

If the wind becomes high before rain begins to fall, the storm is likely to be severe, with heavy rain for a brief period only; but if the rain comes first and the wind gradually increases, it is likely to last for several hours, perhaps with intervals of partly clearing weather.

Thunder-squalls are more dangerous over waterways than over the land as water is a good conductor of electricity, and the wind-rush or squall becomes intensified in passing over a lake or following a river. Small craft should without any hesitancy make for a place of safety on the first indication of a thunder-storm; this may easily be detected in the formation of large cumulus clouds forming into a massive dome, which finally breaks and the bottom becomes a broken mass from which rain begins to fall and lightning flash.

The force of the wind is in proportion to the suddenness and greatness of the fall of the barometer.

In all sudden and great falls of the barometer there is, besides high winds, heavy rain or snow.

While the storm centre is passing a place there is generally a lull in the wind and a slight rise in the barometer, quickly followed by a rapid rise.

During the passing of a general storm the wind shifts from the east by way of the south to the west and northwest.

The day preceding a severe storm is generally clear and mild, especially in winter, with the barometer reading above the average.

In winter, cold waves follow severe storms; the intensity of the cold may be approximated by the greatness of the fall in barometric pressure during the storm. The greater the fall the more intense the cold to follow.

The cold will continue so long as the barometer continues to rise and until it begins to fall.

A rise in temperature will attend a fall in the barometer and *vice versa.*

Cold waves are not to be expected with the barometer reading below 30.00, but seasonal winter cold may prevail when the barometer reads 30.00 or slightly above.

If the barometer rises with a south wind, fair weather is at hand; if it falls with a north wind look for rain or snow.

A rapid rise of barometer in clear weather during winter indicates snow.

A rapid fall during clear weather in winter, snow or rain and fog is likely to follow.

A rising barometer when the air is cold and moist indicates northerly winds and snow or rain.

With a steady barometer and seasonable temperature, fair weather will continue.

A falling barometer, with increasing warmth, indicates that a storm centre is approaching and will pass to the north of you.

Falling barometer, with a dry atmosphere (in winter) indicates snow.

Falling barometer after a calm and excessive heat (in summer) indicates thunder-squall and rain.

On cloudy days the barometer will fall more than on clear days, because the moisture in the air makes it lighter than dry air; the greater the proportion of moisture the more the barometer will fall.

A barometer reading below the average indicates that the atmosphere contains more than the average amount of moisture.

A barometer reading above the average indicates a dryer and more dense atmosphere.

An increase of air over any region causes increased pressure or higher barometer or *vice versa.*

In the winter months the first indication of an approaching storm is observed in the appearance of fine, cirrus clouds at a great elevation; these gradually thicken until the entire sky is covered with sheet-like haze, the atmosphere becomes warmer, the wind light, and working to an easterly point. With these conditions snow or rain invariably follows in from 12 to 24 hours.

The severest storms come with a slowly but steadily falling barometer.

Clearing weather after a severe storm comes with a rapidly rising barometer.

A slowly rising barometer after a severe storm indicates continued cloudiness and unsettled conditions.

With a high barometer, clear sky and light wind in spring or fall, look for frost.

A storm which comes up quickly disappears quickly.

When the temperature shows a material rise for from 12 to 24 hours there is a storm to the northwest or north of you.

When the temperature rises rapidly, the wind will blow from a place of high pressure to the place of lowest pressure; in other words, the wind will blow to the place where a storm is brewing or is already in progress.

A slowly falling barometer, with the temperature at or below freezing point and the wind shifting to south, indicates snow; with the temperature above freezing-point, rain.

The following table of wind directions, showing the quadrants from which the winds *least* likely to be followed by rain or snow are observed to blow during each month of the year, in the several geographical districts of the United States, also those which are *most* likely to be followed by rain or snow, will be found to be of great benefit in foretelling weather changes.

Rules compiled by the Weather Bureau under the direction of Gens. A. J. Myer and A. W. Greely, for use in determining weather changes with the aid of the daily weather map, will be found valuable.

The general movement of storms in the United States is from west to east, and we may liken them to a series of rather rounded atmospheric waves of which the crests are marked "High," and oval troughs or depressions between are marked and

Table showing the quadrants from which the winds *most* blow, during each month of the year, in the several

DISTRICTS.	JAN.	FEB.	MAR.	APRIL.	MAY.
New England	SE to SW	SE to SW	E to S	SE to SW	SE to SW
Middle Atlantic States	N " E	E " S	E " S	E " S	SE " SW
South Atlantic States	N " E	NE " SE	SE " SW	SE " SW	NE " SE
Florida Peninsula	NE " SE	E " S	E " S	S " W	NE " SE
Eastern Gulf States	E " S	E " S	SE " SW	SE " SW	SE " SW
Western Gulf States	E " S	E " S	E " S	E " S	E " S
Rio Grande Valley	E " S	E " S	NE " SE	NE " SE	NE " SE
Ohio Valley and Tennessee	SE " SW	SE " SW	SE " SW	SE " SW	SE " SW
Lower Lakes	SE " SW	SE " SW	SE " SW	S " W	S " W
Upper Lakes	SE " SW	SE " SW	NE " SE	NE " SE	E " S
Upper Mississippi Valley	E " S	E " S	E " S	E " S	E " S
Missouri Valley	NW " NE	NW " NE	E " S	NE " SE	E " S
Extreme Northwest	E " S	E " S	NE " SE	NE " SE	E " S
Northern Slope	SW " NW	SW " NW	SW " NW	NW " NE	NW " NE
Middle Slope	NW " NE	N " E	N " E	N " E	N " E
Southern Slope	N " E	SE " SW	E " S	E " S	E " S
Southern Plateau	S " W	S " W	SE " SW	S " W	SE " SW
Middle Plateau	SE " SW	SE " SW	SE " SW	SE " SW	SW " NW
Northern Plateau	SE " SW	SE " SW	SW " NW	S " W	S " W
North Pacific Coast	SE " SW	SE " SW	SE " SW	SE " SW	S " W
Middle Pacific Coast	SE " SW	SE " SW	SE " SW	SE " SW	SE " SW
South Pacific Coast	E " S	S " W	S " W	S " W	SW " NW

Table showing the quadrants from which the winds *least* blow, during each month of the year, in the several

DISTRICTS.	JAN.	FEB.	MAR.	APRIL.	MAY.
New England	NE to SE	W to N	W to N	W to N	W to N
Middle Atlantic States	W " N	W " N	W " N	W " N	W " N
South Atlantic States	E " S	W " N	W " N	W " N	W " N
Florida Peninsula	W " N	W " N	W " N	W " N	W " N
Eastern Gulf States	W " N	W " N	W " N	W " N	W " N
Western Gulf States	SW " NW	SW " NW	SW " NW	SW " NW	W " N
Rio Grande Valley	SW " NW	SW " NW	SW " NW	SW " NW	W " N
Ohio Valley and Tennessee	W " N	W " N	W " N	W " N	NW " NE
Lower Lakes	NW " NE	NW " NE	NW " NE	W " N	N " E
Upper Lakes	N " E	NW " NE	W " N	W " N	W " N
Upper Mississippi Valley	W " N	SW " NW	W " N	W " N	W " N
Missouri Valley	SW " NW	S " W	S " W	SW " NW	SW " NW
Extreme Northwest	N " E	N " E	S " W	SW " NW	SW " NW
Northern Slope	E " S	E " S	E " S	S " W	S " W
Middle Slope	SW " NW	SW " NW	SW " NW	SW " NW	SW " NW
Southern Slope	SW " NW	SW " NW	SW " NW	SW " NW	SW " NW
Southern Plateau	NW " NE	N " E	NW " NE	N " E	NW " NE
Middle Plateau	N " E	N " E	N " E	N " E	N " E
Northern Plateau	NW " NE	NW " NE	NW " NE	NW " NE	NE " SE
North Pacific Coast	NW " NE	NW " NE	NE " SE	N " E	NE " SE
Middle Pacific Coast	N " E	N " E	NW " NE	N " E	N " E
South Pacific Coast	NW " NE	NW " NE	NW " NE	N " E	N " E

likely to be followed by rain or snow are observed to geographical districts of the United States.

June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
SE to SW	SE to SW	SE to SW	SE to SW	SE to SW	SE to SW	SE to SW
SE " SW	SE " SW	SE " SW	E " S	SE " SW	SE " SW	SE " SW
SE " SW	SE " SW	SE " SW	NE " SE	N " E	N " E	SE " SW
NE " SE	NE " SE	NE " SE	NE " SE	NE " SE	NE " SE	E " S
SE " SW	SE " SW	E " S	NE " SE	E " S	E " S	E " S
E " S	E " S	E " S	E " S	E " S	E " S	E " S
E " S	E " S	NE " SE	NE " SE	NE " SE	NW " NE	N " E
SE " SW	S " W	S " W	SE " SW	SE " SW	SE " SW	SE " SW
S " W	S " W	SE " SW	S " W	SE " SW	SE " SW	SE " SW
SE " SW	SE " SW	SE " SW	SE " SW	SE " SW	S " W	SW " NW
SE " SW	SE " SW	SE " SW	SE " SW	SE " SW	E " S	E " S
E " S	SE " SW	E " S	SE " SW	E " S	NW " NE	NW " NE
E " S	E " S	E " S	NE " SE	E " S	W " N	E " S
SE " SW	SE " SW	NE " SE	NW " NE	W " N	SW " NW	NW " NE
N " E	E " S	E " S	NW " NE	N " E	NW " NE	NW " NE
E " S	E " S	NE " SE	NE " SE	E " S	N " E	N " E
SE " SW	SE " SW	SE " SW	SE " SW	SE " SW	E " S	S " W
NW " NE	SE " SW	SE " SW	SE " SW	SE " SW	S " W	SE " SW
SW " NW	SW " NW	SW " NW	SW " NW	SE " SW	SE " SW	SE " SW
S " W	S " W	SE " SW	SE " SW	S " W	S " W	SE " SW
SE " SW	SE " SW	S " W	SE " SW	SE " SW	SE " SW	SE " SW
S " W	S " W	SW " NW	SW " NW	SW " NW	S " W	E " S

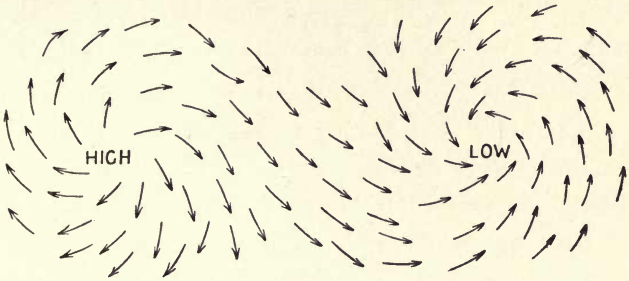
likely to be followed by rain or snow are observed to geographical districts of the United States.

June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
W to N	W to N	W to N	W to N	W to N	W to N	SW to NW
NW " NE	N " E	W " N	W " N	W " N	W " N	W " N
W " N	W " N	W " N	W " N	W " N	SW " NW	W " N
W " N	NW " NE	W " N	W " N	W " N	SW " NW	W " N
NW " NE	NW " NE	NW " NE	W " N	SW " NW	SW " NW	W " N
W " N	W " N	W " N	SW " NW	SW " NW	SW " NW	SW " NW
SW " NW	SW " NW	SW " NW	SW " NW	SW " NW	S " W	S " W
N " E	N " E	N " E	W " N	W " N	W " N	W " N
NW " NE	NW " NE	N " E	NW " NE	NW " NE	N " E	NW " NE
W " N	W " N	W " N	W " N	N " E	N " E	N " E
NW " NE	NW " NE	W " N	W " N	W " N	NW " NE	SW " NW
SW " NW	SW " NW	SW " NW	N " E	SW " NW	NE " SE	S " W
W " N	N " E	SW " NW	S " W	S " W	S " W	S " W
N " E	N " E	SW " NW	E " S	E " S	E " S	E " S
SW " NW	SW " NW	SW " NW	SW " NW	SW " NW	S " W	SW " NW
W " N	W " N	W " N	W " N	W " N	SW " NW	SW " NW
NW " NE	N " E	NW " NE	NW " NE	NW " NE	NW " NE	N " E
S " W	N " E	N " E	NE " SE	N " E	NW " NE	N " E
N " E	E " S	NE " SE	E " S	N " E	W " N	NW " NE
NE " SE	NE " SE	NE " SE	N " E	N " E	NW " NE	NW " NE
NW " NE	NW " NE	NW " NE	NW " NE	N " E	N " E	N " E
N " E	NW " NE	E " S	N " E	NE " SE	NW " NE	NW " NE

called "Low." These alternating Highs and Lows, several hundred miles apart, have an average easterly movement of about six hundred miles per day.

High winds and rain, and, if cold enough, snow, usually precede the low area, often extending to a distance of 600 miles; in advance of the low centre the winds are generally southerly, and consequently bring high temperature. When the centre of the Low passes to the east of a place the wind at once shifts to the north, which brings lower temperature and clearing skies, and in winter cold waves or northers. The temperature on a given parallel west of the Low may be reasonably looked for on the same parallel to the east when the Low has passed, and frost will occur along and north of an isotherm of about 40° if the night is clear and there be but little wind. Following the Low comes an area of High, bringing sunshiny weather, which in its turn is followed by another Low.

By bearing in mind a few general rules as to the direction and rate of movement of the Low and High, with the blowing of the wind from the High towards the Low, coming weather changes may be foreseen by a glance at the map. The centres of Low do not move across isotherms, but follow their general direction.



Circulation of wind out of an area of High into an area of Low pressure.

The cloud and rain area in front of a Low is about the size of the latter and oval, with the west side touching the centre of the Low in advance of which it progresses.

When the isotherms run nearly east and west, no decided change in temperature will occur. If the isotherms directly west of a place incline from northwest to southeast, it will be warmer; if from northeast to southwest, it will be colder. Southerly winds prevail west of a nearly north and south line cutting the middle of a High, also east of a like line cutting the middle of a Low. Northerly winds occur west of a nearly north and south line passing through the middle of a Low and also east of a similar one through the middle of a High.

An absence of decided waves of High or troughs

of Low pressure indicates a continuance of existing weather which will last till later maps show a change, usually appearing in the west.

If the region of low barometer be very small, the area of violent winds will be correspondingly contracted, as in tornadoes on land. Even if no fall in the barometer be noticed, brisk winds may be experienced, owing to the fact that the air in rapid motion overhead may drag along with it that on the surface of the ground, but in general it may be stated that ninety per cent. of the winds that are dangerous to navigators are accompanied by areas of notably high and low barometer. Now, when the barometer falls over any region, the inertia of the surrounding air causes some time to elapse before it is set in motion, and similarly a large mass of air moving with rapidity preserves its motion after the exciting cause is removed. Thus it may happen that strong winds exist in regions at which no barometric disturbance exists at the moment, but has existed a short time previously.

Again, the space inclosing the partial vacuum, into which the wind tends to rush, itself moves slowly over the earth, and thus the wind at any point appears still longer to delay to follow the barometic disturbance. This delay will, of course,

vary with the motion of the central area of low pressure, or that of the neighboring high pressure.

The general consequence of the preceding considerations is that the area covered by the weather-chart presents to our view one, two, or three regions of low pressure, and one or two of high, and that between these, but much nearer to the low than the high barometer, we find the strongest winds. As regards the direction of the winds they may be described as not tending directly to the centre of the area of low pressure, but as circulating around and in upon it in a sinuous spiral in a direction contrary to the movements of the hands of a watch (when it is laid down with its face upwards); thus there are found northerly winds on the west side of the region, westerly ones on the south side, and so around. Of these winds, those from the northwest and southwest are more violent, on the average, than those from the southeast and northeast, but the latter may be more dangerous, and when they pass over smoother ground may be even stronger at the immediate surface of the earth.

The map presents the positions and movements of the larger areas of high and low barometer, of cold and warm weather, or of stormy, cloudy, and

clear weather. In the absence of a weather map, therefore, one can determine in a general way whether these are approaching to or departing from his neighborhood, and this knowledge leads to the following conclusions:

If the barometer is very low at the centre, very severe gales may be expected over a large area, say within a circle of two hundred miles radius, from October to April; but within a smaller circle, less than one hundred miles from May to September.

Areas of low barometer when first perceived in Minnesota may be expected to move eastward in the summer months with westerly winds on Lake Superior, and to move to the southeast and east-southeast in the fall, with east and northeast winds on Superior and Michigan.

When perceived in Nebraska or Indian Territory they may be expected to move northeast to Lake Ontario, with northeast winds on Superior, Michigan, and Huron.

When perceived in Texas or anywhere on the Gulf coast they may be expected to move northward to the latitude of 35° or 40°, and there begin to move northeastward, with northeast, north, and northwest winds on the lakes, and, sub-

sequently, southerly winds on the Middle and East Atlantic coasts.

When perceived on the coast of Florida, or off the South Atlantic, they, in the fall, winter, and spring, may be expected to move slowly up the coast, preceded by northeasterly winds and rain.

Whilst the preceding sentences mark out the most general average phenomena attending the movement of the disturbing areas of low pressure, it must be borne in mind that but very rarely will the ever-varying atmospherical condition allow any storm to pursue a uniform average course over the earth.

The most important condition disturbing the regular movement of a storm is the presence of moist air; that is to say, air nearly saturated with aqueous vapor. Such air is found over extensive forests and marshes, over bodies of warm water, and especially over a field of snow or ice, which is being melted by the sun. Towards these regions the areas of low barometer may be expected to be drawn more or less strongly, or at least to spread out over them.

When the low barometer on the west of the Appalachian chain of mountains causes easterly winds on the Atlantic coast, these force a mass of air up

the eastern slopes of these hills, and this, as it rises, becomes more and more nearly saturated, so that the low pressure west of the mountains may be expected to be rapidly spread over the range, and even transferred, as it were, to the Atlantic coast.

Waves of low pressure on the Pacific coast are also transferred across the Rocky Mountains and the elevated plateaux, and may be expected, when they arrive at the Mississippi valley, to produce cloud and, probably, storm centres.

Besides the disturbing action of moist areas, we have to consider the contrary influences exerted by areas of dry air, such as are found on the eastern slope of the Rocky Mountains. When a storm-centre is driven into such a region, clouds and weaker winds may be expected, and the storm will gradually die out, unless moisture is gathered from irrigation ditches.

Besides the forces attracting the areas of low pressure, we have also to consider the presence of any area of high barometer; this, by causing a system of decidedly strong winds to circulate around it in the anti-cyclonic direction, may drive the storm-centre (whether it be a small tornado, or an extensive cyclone) before it, so as to undergo quite a change in its path.

The general path pursued, day after day, by a storm-centre, is, indeed, the resultant of a system of pressures, some of which arise from the pressures of areas of high and low barometer, some from areas of moist or heated air, some from winds, and others from the rotation of the earth on its axis. These are the important controlling influences; such others as may arise from lunar tides in the air, etc., are considered at present as of inferior prominence.

Whether the observer determines the probable movement of a given storm-centre by means of these general considerations or not, he cannot safely neglect the indications of his own barometer. The experience of the past fifty years has borne uniform testimony to the preeminent value of the indications of this instrument, taken in conjunction, of course, with the wind and weather.

If it be known that a centre of low pressure is in the neighborhood of the observer, and he stand facing it, he will find the wind blowing from some point on his left towards some point on his right: and conversely if he stand with his left hand towards the direction from which the wind comes, he will face the region of lowest pressure. It is better to use, not the direction of the local wind,

but that from which the *low* clouds are moving; the *very high* clouds should not be used.

If, while facing the low pressure, he finds the wind steady, and his barometer falling, then the central area is advancing directly towards him, and, so long as this continues, he may expect the wind to increase until the barometer reaches its lowest; then a lull will take place, followed by strong winds from the opposite quarter, which will continue while the barometer is rapidly rising, but subside as it rises more slowly. The strength of the wind may be expected to be in general proportioned to the rapidity of the fall or rise of the barometer.

The storm-centre has been spoken of as being in front of the observer; it will, however, in general be somewhat more to his right, as he stands with his left to the wind.

If the wind *veer* (that is to say, gradually change its direction, for instance, from southeast to southwest, or, in that order, around the compass), the storm-centre is passing by on the north side of the observer; if it *backs* (changing, for instance, from southwest to southeast), the centre of lowest pressure is passing by on the south side, and the distance at which it is may be roughly estimated by the rapidity of the fall in the barometer.

The severest winds are those, as before stated, on the south and west sides of the centre; those on the east side are more frequently squally.

In the foregoing the observer has been supposed to be stationary; should he be in motion, however, this will affect especially his observation of the barometer, since he may easily run into or away from an area of low pressure, and he himself must mentally allow for the influence of his motion.

Prof. J. P. Espy, an eminent meteorologist, gives the following rules pertaining to storm movement for use in connection with the weather map:

The rain and snow-storms, and even the moderate rains and snows, travel from the west towards the east, in the United States, during the months of November, December, January, February, and March, which are the only months to which these generalizations apply.

The storms are accompanied with a depression of the barometer near the central line of the storm, and a rise of the barometer in the front and rear.

This central line of minimum pressure is generally of great length from north to south, and moves side foremost towards the east.

This line is sometimes nearly straight, but gen-

erally curved, and most frequently with its convex side towards the east.

The velocity of this line is such that it travels from the Mississippi to the Connecticut River in about twenty-four hours, and from the Connecticut to St. John, Newfoundland, in nearly the same time, or about thirty-six miles an hour.

When the barometer falls suddenly in the western part of New England, it rises at the same time in the valley of the Mississippi, and also at St. John, Newfoundland.

In great storms the wind for several hundred miles on both sides of the line of minimum pressure blows towards that line directly or obliquely.

The force of the wind is in proportion to the suddenness and greatness of the depression of the barometer.

In all great and sudden depressions of the barometer there is much rain or snow; and in all sudden great rains or snows there is a great depression of the barometer near the centre of the storm, and rise beyond its borders.

Many storms are of great and unknown length from north to south, reaching beyond the borders of the Gulf of Mexico and on the northern lakes, while their east and west diameter is comparatively

small. The storms therefore move side foremost.

Most storms commence in the "far west."

When a storm commences in the United States the line of minimum pressure does not come from the "far west," but commences with the storm, and travels with it towards the eastward.

There is generally a lull of wind at the line of minimum pressure, and sometimes a calm.

When this line of minimum pressure passes an observer towards the east, the wind generally soon changes to the west, and the barometer begins to rise.

There is generally but little wind near the line of maximum pressure, and on each side of that line the winds are irregular, but tend outward from that line.

The fluctuations of the barometer are generally greater in the northern than in the southern parts of the United States.

The fluctuations of the barometer are generally greater in the eastern than in the western part of the United States.

In the northern parts of the United States the wind generally in great storms sets in from the north of east and terminates from the north of west.

In the southern parts of the United States the wind generally sets in from the south of east and terminates from the south of west.

During the passage of storms the wind generally changes from the eastward to the westward by the south, especially in the southern parts of the United States.

The northern part of the storm generally travels more rapidly towards the east than the southern part.

During the high barometer on the day preceding the storm it is generally clear and mild in temperature, especially if very cold weather preceded.

The temperature generally falls suddenly on the passage of the centre of great storms, so that sometimes, when a storm is in the middle of the United States, the lowest temperature of the month will be in the west on the same day that the highest temperature is in the east.

How to Forecast the Weather by the Appearance of the Sky at Sunrise and Sunset. —Who has not admired the beautiful touch of nature's artistic colors at sunrise and sunset?

The artist has tried in vain to reproduce them; they are not alone beautiful, but they speak volumes, to those who can translate their meaning;

each color possesses a distinct meaning of its own.

Joy or distress is often pictured on the face of those who follow the sea and are guided by these telltale colors indicating what the coming day is to be.

The sailor trusts as much to the colors of the sky at sunrise and sunset as he does to his barometer.

Some of the most important and reliable forecasts may be given as follows:—

A yellow sunset blended with orange indicates a fair day, with light breeze.

The glowing color of the western sky at sunset is the local sign that the coming morning will be fair.

A sunset marked by beautiful and slowly fading colors, from white to orange to red, is considered as presaging a fair day.

The setting of the sun as a red disk of fire presages warmer weather on the morrow.

A fiery glow under a canopy of clouds foretells high wind.

The sunsetting in a cloud indicates a change from fair to wet weather.

So long as the sun rises high or sets in a cloud, wet weather will follow or continue, if at hand.

Pale green near the horizon at sunset presages

fair weather, but a dark grayish green foretells stormy conditions.

If the day grows excessively warm and towards evening the clouds seem to rest on the western horizon and become grayish at the base, if the wind dies away and the atmosphere seems unusually quiet,—it is the best evidence of a coming thunder-storm.

A greenish color at sunset is a sign of rain.

When the clouds near the horizon take the appearance of land, there is bad weather ahead.

A glow over a cloudy sky at sunrise means stormy weather.

If the sky at sunrise looks threatening, look to the westward; if that quarter is bright, a fair day is at hand.

There is virtue in the old saying: "A rainbow at night is the sailor's delight; but a rainbow in the morning,—sailors, take warning."

A bright-yellow sky at sunset presages wind and rain.

A pale-yellow sky foretells rain.

A sun that sets in a sullen bank of red is treacherous; storm close at hand.

Dark green blending into red means rain.

A sunset without clouds presages fair weather.

Light delicate tints with soft forms of clouds at sunset presages fair weather.

Hard and strongly defined clouds, with decided gaudy hues at sunset, foretell wind and rain.

Mild tints of red at sunset indicate fair weather for the following day.

A red and lowering sky at sunrise presages a wet day.

A gray morning indicates a fine day.

A gray sunset indicates rain.

A red sunrise, a wet day.

A red sunset, a fair day. Hence the proverb:

> "Evening red and morning gray
> Will set the traveler on his way,
> But evening gray and morning red
> Will bring down rain upon his head."

If the sun appears to be setting in a fog, with dark crimson streaking the horizon, wind and rain may be expected on the following day.

To Forecaste by the Clouds.

Clouds.—Clouds are among the most reliable of the natural phenomena to be considered in calculating changes of the weather, and to aid those who have no other means of determining such changes, some of the cloud signs are here given.

Cirrus clouds are the first indication of a change after a day or two of fair weather. The interval of time between their appearance and the beginning of rain or snow is not always the same.

If there is an accumulation of clouds in the evening, it is a good indication of a surplus of moisture in the air, which with the loss of heat of the day cannot be sustained and must be condensed as rain or snow.

A mottled sky at any season of the year presages fine weather.

Cirrus clouds forming a mackerel sky foretell rain and sometimes a heavy storm of wind and rain.

Streamers of cloud resembling mare's tails stretching from the horizon to the zenith indicate wind.

A gray and low overcast sky with apparently no movement and northerly wind indicates snow in autumn and winter.

A gray sky in the morning promises fair weather.

Dark, gloomy, blue skies foretell wind.

A light blue sky indicates fair weather still to come.

Jagged, torn clouds announce the advent of wind.

A "high dawn,"—when the sun first appears above a blanket of clouds—forebodes wind.

A "low dawn,"—when the sun first appears near the horizon, means fair weather.

The softer the clouds appear, the milder the wind.

Any change in the color of clouds from mild to harsh means a change of weather or wind.

Anvil-shaped clouds are likely to be followed by a gale.

If small, white clouds are seen to draw together, their edge becoming broken, expect wind.

Cirrus clouds, with the feathery tips turned up, indicate rain; with feathery tips turned down, fair weather.

Heavy rolling clouds in front of thunder-storm denote high wind.

Small inky-looking clouds foretell rain.

Light scud clouds driving across heavy clouds indicate wind and rain.

Upper clouds moving from the west towards the east, with lower clouds moving from east rapidly towards the west indicate the approach of heavy storm, with high easterly winds.

Fog forming in the morning is an infallible sign of a fair day.

If fog sets in during the night, a misty or rainy day may be expected.

When smaller clouds melt into one another, fair weather will continue.

Misty-looking clouds forming or hanging over cliffs or heights indicate wind and rain; if they rise or disperse, fair weather will follow.

When the sky in summer is partly covered with large, beautiful, well-outlined cumulus clouds, fair weather will continue.

Small rounded tufts of cloud (cirro-cumulus) foretell dry, hot weather.

Mackerel skies (cirrus clouds) invariably indicate rain or wind, probably both.

> "Mackerel's scales and Mare's tails
> Make lofty ships carry low sails."

Dew or frost never occur on a windy night.

Dew forms heaviest after a hot day.

Three days of frost, then rain.

How Weather Changes are Foretold by the Sun, Moon and Stars.—As a matter of fact, deductions from years of study have demonstrated that there is no connection between astronomy and meteorology, except a slight relationship in atmospheric electricity; and nothing definite has been determined in this direction. So that those phenomena which might be pointed out as indica-

ting weather changes would in no way be attributable to the planets, but to existing atmospheric conditions.

Scintillation of Stars.—The records of the Astronomical Observatory at Brussels are said to show that among the influences having the greatest effect on the scintillation of the stars, that of rain is most predominant, at every season scintillation being notably more marked under such influence than under that of dryness—much stronger in winter than in summer, particularly in January and February, and least noticeable in June and July. The data show that the intensity of the phenomena increases progressively at the approach of rain and especially during rainy days, diminishing when the rain ceases. When it has rained on the day of observation scintillation appears notably stronger on the next day and the day after. The intensity also greatly increases at the approach of sudden squalls, so that when these great atmospheric disturbances occur, it attains a maximum, diminishing in proportion as they recede. The temperature of the air is found to exercise a marked influence on the character and intensity of scintillation and this is particularly the case during periods of dryness. When the temperature lowers, especially in winter, scin-

tillation is strong and the colors very brilliant; when it grows warmer, the intensity diminishes and the colors lose much of their brilliancy and brightness, especially in summer.

HALOS.—Halos around the moon or sun are precursors of wet weather.

Very brilliant starlight; stars very low, and numerous stars, indicate rain.

The number of stars in halo, the number of days before rain.

The halo indicates rain or snow, because it shows the upper atmosphere to contain considerable moisture.

A pale moon indicates rain. The pale appearance is probably due to the upper regions of the atmosphere being covered with a thin veil of cirrus cloud. Although not visible, except when they cover the moon, they are the forerunners of a storm.

If the full moon rises red, look for wind.

Haze around the sun or moon indicates excessive moisture and rain.

WEATHER PROVERBS.—In the absence of the natural tact and quick precision of observation possessed by the sailor, the agriculturist and those whose calling requires close attention to weather

changes, and where a knowledge of such changes is of material importance, many adhere to weather proverbs based on the action of animals, birds and insects, as well as signs and omens, which for ages have been esteemed the best means of foretelling weather changes. They cannot be considered as of any value and are given only because they are in common use.

Old mythology is called upon to emphasize the proverb that "dolphins or porpoises around a ship is a sign of rain."

"The appearance of sea-mew is an indication of rain."

"Sea-gulls in the field is a sign of a storm."

"Geese rubbing down and dressing their feathers is a good sign of fair weather. If the geese keep away from the water, look out for a good old-fashioned storm."

"When geese feed and finally go to the water the weather will clear."

"The frightened cry of geese means rain coming."

"Roosters are said to clap their wings in an unusual manner before rain, and hens rub in the dust and seem very uneasy."

"Cats with their tails up and hair apparently electrified indicate approaching wind."

"When wild geese fly south, expect cold weather; when they fly north, expect warm weather."

> "You can tell by two what it's going to do.
> Rain before seven shine before eleven."

> "If Candlemas day be fair and bright,
> Winter will take another flight.
> If Candlemas day be dark and drear,
> Winter is gone for all that year."

"Bees remain in their hives preceding rain."

"Swallows fly low before approaching rain."

"Sea-gulls fly about the sea when the weather is fair and disappear on the approach of rain or stormy weather, or fly over the land."

"Petrels fly to the sea before a storm and remain over the sea till the storm passes."

"Corns ache previous to rain, because the feet swell on account of a less dense atmosphere."

"Cats rub their ears when it is likely to rain, because moist air is charged with electricity which produces an itching sensation."

"When sheep lie around and are unwilling to go to pasture, it is a good sign of rain; damp air makes them listless and drowsy."

"If swine be restless and grunt loudly, there will be much wind."

"Magpies flying in flocks and uttering harsh cries foretell windy weather."

"Before rain, fowl of all kinds make unusual noises."

"Before a rain, horses neigh, cattle low, asses bray, and sheep bleat, because dampness relaxes their nerves and they feel restless."

"Spiders weaving their webs means a spell of fine weather."

"If the wishbone of the goose be dark blue or black, the coming winter will be very cold."

"When the husk of the corn grows tight to the ear, expect a cold winter; when loose, a mild winter."

"When leaves hang to the trees late in the Fall there will be plenty of snow."

"Heavy coats of fur on fur-bearing animals show that the winter will be severe."

"Apples falling in quantities from the trees is an indication of a mild winter."

"A scarcity of acorns and nuts foretells a mild winter."

"If the corn husks are thick the winter will be cold; if thin, the winter will be mild."

"If the rabbit sits erect, it means a mild winter."

"If the horse sheds his hair profusely, the winter will be mild."

"If there is a thaw between Christmas and New Year's, a thaw in all the winter months is to be expected."

"A green Christmas, a fat graveyard."

"When snakes remain in sight in the late Fall it is a sign of an open winter; snakes take to their holes four weeks before winter sets in."

"When wasps build their nests loose to the ground it is a sign of a mild winter."

"Musk-rats show unusual activity in building their nests when a severe winter is at hand."

Miscellaneous Conditions.

Unusual clearness of the atmosphere, making distant objects appear nearer, is a sign of rain within 24 hours.

Foul odors are more noticeable in the air prior to rain, because the increased vapors prevent them from rising as in dry weather.

Flowers are more fragrant previous to rain; their perfume is prevented from rising on account of excessive humidity.

Prior to rain, smoke will descend instead of

rising, on account of the air being less dense, which indicates excessive moisture.

When the atmosphere is dry and fair weather likely, fires will be observed to burn briskly and smoke ascend.

Previous to a storm, especially in the warmer weather, one feels enervated and oppressed, because the air is rarefied by heat and vapor, and the air within us seeks to become of the same rarety, producing a feeling of suffocation.

Sounds from a distance are more distinctly heard during clear and dry weather than prior to rain, when the air is humid and sound is not so easily propagated; in other words damp air muffles sound.

Weather Indications by the Polymeter.

Fore-knowledge of the changes of the weather is of great importance to the generality of people, and is especially valuable to seamen leaving or entering port, to merchants in shipping goods, to gardeners and farmers on account of planting and reaping their crops, to builders in successfully attending to their work and ordering material; to physicians weather indications are of great importance as to the welfare of their patients.

Heretofore the indications of the weather were obtained from expensive barometers, wind-gauges, and thermometers. Now the inexpensive polymeter gives extremely reliable indications of the coming changes of the weather.

To obtain correct weather readings by the polymeter it requires that the instrument be placed in the open air and shade the same as any other meteorological instrument, where it will not be influenced by the direct heat of the sun. For the maintenance of a healthy atmosphere in the house, it is desirable to have a polymeter in each room, so as to know what is the temperature and percentage of moisture of the rooms.

If the polymeter in the house should indicate 75 per cent. or more humidity, and a fall of temperature occur, the moisture in the air would deposit and dampen our clothing, bedding, furniture, walls, etc. This deposit of moisture can easily be prevented by lighting a small fire, and thus raising the temperature inside the house.

Should the polymeter in the room indicate 40 per cent. or less humidity, then such air would prove very uncomfortable, the throat become parched, the skin dry, the furniture shrink and crack, and plants would wither and die. Evapora-

tion of water under these conditions is absolutely necessary to render the atmosphere suitable for health.

Polymeter Dew-Point Rules.

1.—A rising dew-point indicates warmer weather.

2.—A falling dew-point indicates cooler weather.

3.—A rapidly rising dew-point indicates a distant thunder-storm, particularly in spring and summer.

4.—A high dew-point, or humidity of 70 degrees or more, with a muggy atmosphere, indicates a thunder-storm. This damp weather is very oppressive to the human system, because the lungs are not able to perform their functions properly by arterializing the blood, hence asthma and pulmonary troubles.

5.—A falling dew-point, with temperature at 32 degrees or lower, indicates frost, especially when the sky is clear.

6.—A rapid fluctuating dew-point indicates wind.

7.—A higher dew-point at 6 P. M. during the summer than the mean temperature during the middle of the day, indicates a thunder-storm.

8.—When from 3 degrees to 6 degrees on the dew-point scale which is above the humidity scale,

indicates fair weather with certainty, even under unfavorable atmospheric conditions.

9.—The more constant the limits of variations of the temperature and dew-point the more constant the coming weather.

10.—The greater the changes between the temperature and the dew-point the greater the probabilities for rainy or stormy weather.

11.—After sunset, especially during a clear sky, a temporary rising of the dew-point may be perceived in consequence of a rapid and unequal cooling of the lower strata of the air. In this case it is not certain if it is a general or a local increase in the quantity of vapor, but if an observation is taken from the polymeter a few hours after twilight a correct forecast can be made.

12.—Owing to the changeable character of the weather the observer must note from time to time the changes in the indications of the polymeter, and he must not expect to forecast the coming weather by a casual look at the instrument. If, for instance, at 2 P. M. the finger of the polymeter points to 4 degrees on the upper scale of the dew-point figures, it would indicate a vapor-ladened atmosphere. At 4 P. M. a rise

is noted to 5 degrees, and again at 6 P. M. a further rise to 6 degrees—fine weather may be safely predicted for the coming day.

The Value of Snow Covered Ground.

The value of snow-covered ground, and its influence on weather and climate are shown by a very careful study of the subject by Prof. A. Woeikof, of Bavaria.

The observation and study of this subject in the United States would be of material benefit to the farmer and horticulturist.

1. The snow, as a bad conductor of heat, protects the ground from cooling during the entire time that the temperature of the air and of the surface of the snow is below the freezing point.

2. This effect is, with equal depth of snow, the greater in proportion as the snow lies lighter. It is notably less when the snow is soaked with water or is icy.

3. At temperatures above 32° the effect of the snow is the opposite, that is cooling. This cooling effect lasts after the snow is melted, because the soil is then filled with water at 32°, and this warms up slowly.

4. On the whole, therefore, the snow lessens the fluctuations of the temperature of the ground.

5. The warming effect of a snow covering is greater than the cooling, and the more, the longer the snow continues in temperatures below freezing. With a snow covering of twenty inches depth and over six months continuance, the temperature of the soil at a depth of three feet is probably not lower in the coldest months than the annual temperature of the surface or that in the lower layers of air.

6. By the surface is here meant the surface of the snow when present, and of the soil when there is no snow.

7. The temperature on the surface of soil free from snow is higher than that of the surface of the snow.

8. This is due to the physical properties of the snow,—on its capacity for radiation, on the impossibility of warming it above 32° without melting, and on its bad conducting power which, so to speak, concentrates the cold on the surface.

9. Since the temperature of the lower layers of air depend to a great degree on the temperature of their bed, whether this is solid or liquid, this temperature must be lower, other things equal, over snow than elsewhere.

10. As the cooling of a snow surface, as compared with one free of snow is greater in clear than cloudy weather, this relation must also hold for the lower layers of air.

11. The cooling of the air over a snow layer is so great that it can be shown by ordinary meteorological observations without requiring the use of especially sensitive instruments.

12. When snow lies on the ground, we generally have a so-called reversal of the temperatures; that is, the lowest air layer is colder than that somewhat higher; this may happen in the middle of the day, especially in calm and clear weather. The reversals of temperature between valleys and neighboring heights, that is, lower temperature in the first, happens most often over a snow surface.

13. The rough surface of the snow and the cold air lying over it lessen the force of the wind.

14. This tends to preserve the snow surface by weakening the effect of warm winds.

15. The lessened wind velocity and also the colder air are favorable to the formation and continuance of anti-cyclones over a snow surface.

16. The blizzards often so terrible, are by no means always accompanied by wind strong enough to cause injury to buildings, trees, etc. Their in-

jurious effects are due to the driving snow, and it is that that robs men and cattle of their senses.

17. On account of the evaporation of the snow, the relative humidity is greater over a layer of snow than without it.

18. The evaporation of the snow is small, because its surface is at a lower temperature than the air.

19. The influence of a snow covering on the cloudiness differs with the circumstances. The greater relative humidity is favorable to a greater cloudiness, while with the anti-cyclones, favored by the snow, there is usually little cloudiness.

20. The impossibility of warming snow over 32° has a great influence on the temperature of the air. Thawing weather in winter over an extended covering of snow is of short duration; the temperature rises but little over 32° and that only as long as the warm wind lasts. With cessation of wind and clearing sky, the temperature rapidly sinks below freezing.

21. In spring (in lower latitudes in winter also) there are days when, in calm weather and full sunshine, the temperature rises above freezing, even while the snow lasts. In these cases the air is warmer than the snow. When there is no snow, in

full sunshine, the surface of course is always notably warmer than the air. The phenomenon above mentioned is always of short duration and has no great effect on the mean temperature of the air.

22. The snow thaws but little, if at all, under the direct sun's rays, as long as the air temperature is below freezing. Hence, the melting of snow in quantity only begins when a mass of warm air from a region free of snow, or from a sea free of ice, has raised the air temperature above freezing.

23. On the northern hemisphere, therefore, the melting of snow proceeds by steps from south to north, and from west to east because the seas to the east of both continents are cold.

24. Without the influence of warm air, the air temperature remains below 32°, even in May and June, in high latitudes, so long as the snow remains.

25. On the northern hemisphere in summer, up to the highest latitudes, there is enough water free of ice or land free of snow to provide in June a sufficient flow of warm air to bring about the melting of snow in quantity. Even in the highest latitudes the snow melts during the summer on the plains and the seacoast and the temperature is above 32° for a month or two.

26. That this phenomenon is not universal ap-

pears in the higher latitudes of the southern hemisphere, where, south of 62° S, the mean temperature, even in midsummer, is below 32°. At 78° S it is even under 25°. Here the warm air has to traverse a distance of 600 miles over a water surface cooled below freezing; it is thereby so much cooled that it cannot thaw the snow of the south polar continent.

27. The low temperatures which occur in regions without snow covering, as on the plains of Turkestan and the plateaux of central Asia, can be attributed to the following causes: (*a*) In some cases snow falls and is generally followed by intense cold due to radiation. It is very severe because there is little cloudiness and the air is diathermanous. (*b*) Especially in central Asia, the winds are strong, the air is dry, the soil dries to a great depth and becomes a bad conductor of heat. Its surface then cools rapidly, especially if it is sandy. (*c*) Low temperatures are often brought by winds from countries covered with snow, as on the plains of Turkestan from western Siberia.

28. The melting of the snow affects the rivers greatly, and on it depends the regular high water of the rivers of European Russia and west Siberia.

29. The height of water in small rivers and

brooks in spring depends not only upon the quantity of snow lying on the ground, but also upon its more or less rapid melting and on the circumstance whether the ground is frozen to a great depth or not. If the former the soil is impenetrable for the water and the latter quickly reaches the streams. If deep snow has fallen on unfrozen ground, on its melting very much of the water passes into the soil, as in the spring of 1888 in central Russia.

30. The air temperature on isolated mountains depends much less on that of the surface than that of the valleys and plains; hence a covering of snow is in this case of relatively little influence.

31. A snow layer on mountain ridges cools the air in spring and summer to a notable degree and so causes often an unstable equilibrium of the air layers, in a vertical direction.

32. The Bora of the east coast of the Adriatic and of the Black Sea is especially violent when there is the unstable equilibrium which is due to the contrast of temperatures between the snow-covered mountain chains and the warm seacoast.

33. The mountain streams, which are fed by glaciers and compacted snow, have often much water in dry years because at such times more

snow melts than falls. Years of abundant snowfall in the region of continuous snow are not always followed by high water in the streams, because then the snow mass is increased.

34. The snow which falls in mountains has a marked effect on the weather which follows in the valleys and on the plains at the foot of the mountains,—and not only on the temperature, but also on the air pressure and the rain. This has been proven for northern India and has been shown to be very important for the prediction of the weather.

35. The influence of a snow layer on air pressure, temperature and humidity always increases with the extent of the territory covered; hence more anti-cyclones and a lower temperature are to be expected in the centre of a territory covered with snow than at the edges.

36. The snow lying on the ice and ground in high latitudes lessens to a considerable degree the cooling of the solids and of the water.

TEMPERATURES INJURIOUS TO FOOD PRODUCTS IN STORAGE AND DURING TRANSPORTATION, AND METHODS OF PROTECTION FROM THE SAME.

The following, a copy of a pamphlet issued by

the United States Department of Agriculture (Weather Bureau) Relative to *Temperatures Injurious to Food Products in Storage and During Transportation, and Methods of Protection From the Same*, may be of value to those interested in the shipment or storing of perishable goods.

The information, some of which was gathered by the writer, is from the most reliable sources, principally business houses interested in this line of work.

The object of this bulletin is to furnish information regarding the temperatures that are injurious to food products and other perishable articles, under different conditions and during shipment, and to suggest methods of protecting the same from extremes of heat and cold. This information is largely a compilation of the opinions of merchants and shippers in all parts of the country, which were received in reply to a circular letter sent out by the Weather Bureau, and contain much that will prove of interest and value to the public generally.

In the transportation of perishable freight there are three primal objects to be attained:

1. The protection of the shipment from frost or excessive cold.

2. The protection of the same from excessive heat.

3. The circulation of air through the car, so as to carry off the gases generated by this class of freight.

Temperatures for Shipping Perishable Goods.

The temperatures at which perishable goods are liable to damage vary greatly with different commodities, their condition when shipped, how long they may be in transit, whether they are kept continually in motion, etc. Injury is liable to occur from long exposure to a temperature below 32°, or from a shorter exposure to a greater cold, so that the duration, as well as the intensity, of the cold must be considered.

The degree of cold to which perishable goods may be subjected without injury depends on the time the shipment will be on the road; also, whether it will be unloaded immediately upon arriving at its destination or allowed to stand some time, also direction of shipment, whether towards a cold area or away from it.

Shucked oysters shipped in their own liquor in tight barrels will not spoil if frozen while in transit. Thick or fat clams or oysters will not freeze as readily as lean ones, as the latter contain much more water.

Oysters will not freeze as readily as clams. It is safer when oysters or clams in the shell are frozen to thaw them out gradually, in the original package, in a cool place. Clams and oysters in transit through a snow-storm will not freeze as readily as when the weather is fair and a stiff wind prevails.

Shippers and agents concur in the statement that danger in transportation by freezing can be practically eliminated by the shipment of produce by modern methods; the lined car suffices in spring and autumn, and usually during the winter, while in extreme weather the Eastman heater car is used. The temperature of the produce when put into the car is quite a factor to be observed. If it has been exposed to a low temperature for a considerable time before, it is in a poor condition to withstand cold, and the length of time so exposed should be taken into account. It is also claimed that a car load of produce, like potatoes, will stand a lower temperature when the car is in motion than when at rest.

In ordinary freight cars perishable goods can be shipped with safety with the outside temperature at 20°, and in refrigerator cars at 10°. In the latter, these goods may be safely shipped with a temperature outside of from zero to 10° below, if the car is

first heated, and at the end of the journey the goods are immediately taken into a warm place without being carted any great distance. The better class of refrigerator cars will carry all perishable goods safely through temperature as low as 20° below zero, provided they are not subjected to such temperatures longer than three or four days at a time, while with the ordinary refrigerator cars temperatures of zero are considered dangerous, especially if the goods they contain be of the most perishable kind.

Beer can be shipped at an outside temperature of 10° if placed in a refrigerator car and the kegs packed in hay or sawdust and fresh stable manure, the packing being 6 inches or more all around. Bottled beer that has passed through a low temperature during transit should be placed in a cellar and allowed to regain a normal temperature slowly, otherwise it is liable to spoil.

Roses and cut flowers will not be injured unless the temperature falls to 32°. Roses need as low a temperature as possible without freezing, because they are shipped as buds and would develop if the temperature were high.

As a rule, truckers will not haul vegetables to the cars for shipment when the temperature reaches

20°, or lower, and in no case when it is near 32°, if raining or snowing.

Articles shipped from the North to the South during winter should be in a perfectly dry condition.

In shipping early vegetables to a northern market from the South, for distances requiring more than forty-eight hours to cover, open-work baskets, slatted boxes, or barrels with openings cut in them, should be used to allow a circulation of air.

It is not safe to ship olives in any car, unless heated artificially, when the temperature is below 25°.

In shipping green meats the almost universal practice is to ship in refrigerator cars where the temperature can be maintained at any desired degree, a temperature from 36° to 40° being considered the best.

Fresh beef for shipping should be chilled to a temperature of 36°, although under favorable conditions it will arrive in a good state if chilled to only 40°. The cars should be at the same temperature as the chill rooms, and it is considered very important to have an even temperature from the time the beef is taken from the chill room until its arrival at its destination.

In shipping long distances in summer, it is neces-

sary to re-ice the cars, the frequency depending on the prevailing temperature, so that no fixed rule can be given. In winter, the temperature is kept up to 30° by means of stoves or oil lamps.

If refrigerator cars are not used, the meat should be wrapped in burlaps and the carcasses hung so as not to touch each other. With an outside temperature of 50°, or below, in dry weather, meat that has been thoroughly cooled will keep a week if shipped in an ordinary box car. Pork is injured more quickly by high temperature than other meats, and greater care should be taken with it in storing and shipping. Sudden changes in temperature of from 10° to 20° are very injurious to green meats and should be provided against when possible.

Poultry, if shipped at a temperature of 50° and up, should be packed in ice and burlaps; if under 50°, in dry weather, no extra precautions are needed.

Milk for shipping requires great care to prevent souring; it should be reduced after drawing to a temperature of 40°, which extracts the animal heat. It should neven be frozen, as it becomes watery and inferior in quality when thawed out.

Butter should not be frozen unless it is to be used soon after thawing; it freezes at 15°, and when thawed becomes strong quickly.

It is important to note that in shipping fruits, etc., many of the precautions taken in packing to keep out the cold will also keep in the heat, and there is really more danger in some instances from heating by process of decomposition than from cold. All fresh fruit tends to generate heat by this process. A car load of fresh fruit approaching ripeness, closed up tight in an uniced refrigerator car with a temperature above 50°, will, in twenty-four hours, generate heat enough to injure it, and in two or three days to as thoroughly cook it as if it had been subjected to steam heat. Suitable refrigerator transportation must, therefore, provide for the heat generated within as well as to protect it from the outside heat. The perfection of refrigeration for fruit is not necessarily a low but a uniform temperature; a temperature from 40° to 50° will keep fruit for twenty or thirty days if carefully handled. Strawberries have been transported from Florida to Chicago, transferred to cold storage rooms, and remained in perfect condition for four weeks after being picked.

Fruit that has been subjected to a high temperature before being shipped should be cooled immediately after being loaded. Ordinary refrigeration will not cool a load of hot fruit within twenty-four

hours, and during that time it will deteriorate in quality very much. It should be cooled in four or five hours in order to prevent fermentation.

Precautions taken in shipping to protect from cold are papering, packing in straw or sawdust, boxing, barreling with paper lining, shipping in paper-lined cars, refrigerator cars, and cars heated by steam, stoves, and salamanders.

Cars containing perishable goods are sometimes, when a north wind is blowing on the prairie, covered with canvas on the north side.

In winter time refrigerator cars are used without ice in forwarding goods from the Pacific coast, and in passing through cold belts or stretches of country the hatches are closed, and the cars being lined and with padded doors, the shipment is protected against the outside temperature; but in passing through warmer climates the ventilators of cars are opened in order to prevent the perishable goods from heating and decaying.

It is stated, however, that for the shipment of fruit the ordinary refrigerator car is not entirely satisfactory, and that there is a strong demand for a better refrigerator car than can now be obtained. A car is wanted that will carry oranges, bananas, etc., without danger of chill through the coldest cli-

LIBRARY OF THE UNIVERSITY OF

mates of the country, as the delays in housing are injurious to the keeping properties of the fruit, and the dealer is also kept out of the use of his goods.

To protect goods shipped in an ordinary car the sides of the car should be protected by heavy paper tacked to the wall and by the addition of an inner board wall a few inches distant from the other one. A car thus equipped and packed with produce, surrounded by straw, will retain sufficient heat to prevent injury for twenty-four hours, the average air temperature of all parts of the car being at least 12° higher than that of the outside air. Cars are sometimes warmed by steam from the locomotive when in motion, and by stoves when steam is not available. Cars after being loaded are carefully inspected as to temperature within, their destination considered, and if the weather is exceedingly cold, or is liable to be, the car is often accompanied by an attendant; otherwise it is inspected from time to time on the road. Lined cars, that is, cars lined with tonged and grooved boards on the sides and ends, are considered the best by heavy shippers of potatoes, as they can be heated by an ordinary stove, and will stand a temperature outside of 20° below zero, when a man is in charge to keep up the fires. The potatoes are packed in straw, bulkheaded

back, centre of car left empty, and car filled as high as double lining; when the temperature is 12°, or more, below freezing, the rule is to line the barrels with thick paper, and at extremely low temperatures, as a matter of extra precaution, the barrels are covered over the outside with the same kind of paper, which is considered the best known protection from frost.

Oranges shipped from Florida to points as far north as Minnesota are started in ventilator cars, which are changed at Nashville to air-tight refrigerator cars, the ventilators of which are kept open, provided the temperature remains above 32°, until arrival at St. Louis, from which point the ventilators are closed and the cars made air-tight.

Oranges loaded in ventilated or common cars should be transferred to refrigerator cars when the temperature reaches 10° above zero; in transit, with a falling temperature, the ventilators should be closed when the thermometer reaches 20°, and with a rising temperature the ventilators should be opened when it reaches 28°. For lemons the minimum is 35° for opening and closing the ventilators, and for bananas 45° for opening or closing. Some shippers say that ventilators on cars containing bananas, lemons, and other delicate fruits should

be closed at a temperature of 40°. In shipping car loads of bananas, a man is usually sent in charge to open and close the ventilators. Bananas should be put in a paper bag and a heavy canvas bag, and then covered with salt hay, but when put in automatic heaters the fruit is packed only in salt hay.

French mustard and aqua ammonia are packed in sawdust and securely boxed, being careful to allow the sawdust to form a layer between the articles and the side of the box.

Eggs are packed in crates with separate pasteboard divisions, with a layer and a cover of oat chaff.

Quinces, apples, onions, and pears are packed in barrels, each layer of barrels covered with and resting on straw.

Tomatoes, lemons, and oranges are packed in crates; each layer of crates in the car is covered by and rests upon straw, usually bulk-headed back from the door and car full.

Shrubs and fruit trees are laid on straw, covered with it on all sides, and car packed full.

Flowers are packed in moss and car filled.

Flowers, shrubs, and trees should have their roots carefully packed in straw and the roots placed together in two or three piles, so as to protect them;

if the roots are killed they are of a uniform black; if only injured by frost the root is pinkish in color just below the outer covering, and if sound they are of uniform white. Even if of a dark pink color no damage need result, if the frost is gradually thawed out by the trees being left in the closed car for four or five days, or else put the roots well down in the soil in a horizontal position and thaw out gradually. Extra precautions are taken with trees, etc., when passing over mountains, and no shipments should be made when the temperature is likely to be zero anywhere in the higher regions.

During cold weather oysters and clams should be shipped in tight barrels lined with paper.

Products sent loose in a car are packed in straw on all sides, particular attention being paid to the packing around doors, and to see that the car is full. Certain classes of goods, embracing peaches, melons and grapes, are taken by some railroads in no other way.

In shipping perishable goods it is well to cover them with two sheets of heavy paper, weighing about 1¼ pounds each. Manure is largely used to protect perishable goods, the bottom of the car being thickly covered with it, and in some cases it is put on top of the goods.

The relation between the outside air temperature and the temperature within the car varies largely, depending on the kind of car, whether an ordinary freight or refrigerator car, whether lined or not, whether standing still or in motion, and also on the weather, whether windy or calm, warm or cold.

In an ordinary freight car the difference ranges from 2° to 15°, and in a refrigerator car from 15° to 30°. If the latter be provided with heating apparatus, the temperature in winter can be kept at any required degree. For ordinary winter weather, the temperature ranging from 10° to 30° above zero, the refrigerator cars may be used for shipment to any distance without being heated.

From six observations taken at intervals of ten minutes it was found that on a warm day, when the mean of the six readings outside was 68°, it was 66° on the inside of an ordinary freight car and 63° inside of an uniced refrigerator car. On a cold day the mean of six observations was 38° outside and 35° inside of an ordinary car, and 36° inside of a refrigerator car; the car was stationary.

Freight from the Pacific coast to the Mississippi valley, or to the Atlantic coast, has to pass through several varieties of climate at any time of the year. It is therefore obvious that at one time the tem-

perature inside of the car will be materially above the outside temperature, while perhaps a few hours later it will be below.

Food Products in Storage.

The best storage for apples and potatoes and for vegetables generally is a well-ventilated, dry cellar kept at a temperature between 30° and 45°. Other methods of storing potatoes in winter are: In tent-shaped houses, ventilated at the top and covered with earth from six to twelve inches deep; packing in shallow pits in the ground between layers of straw or cornstalks, a layer of straw or cornstalks on top covered with earth, a hole being left in the top for ventilation; and packing in dry sand in cellars.

Apples and potatoes are also stored in specially constructed barns, made as nearly air-tight as possible, fitted with crates or bins, and supplied with heating apparatus for maintaining an even temperature.

Apples keep better if, before storing, they are put in piles out of doors and allowed to sweat.

Potatoes should not be left in the sun after being dug, as the heating induces sweating and decay.

Celery is stored in an unfloored, inclosed, well-ventilated shed, the earth is well wetted, and the celery packed in an upright position, with narrow lanes about two feet apart for ventilation. The temperature should be kept as near 32° as possible; a temperature of 60° to 65° injures it.

Young fruit trees, flowering shrubs, and plants are injured by temperatures below 36°. They are stored in cellars packed in straw, and generally shipped in the same manner as potatoes as regards packing.

Where fruits, vegetables, etc., are kept in cold storage, the following temperatures are considered most favorable, viz., for apples, apricots, berries, buckwheat flour, oatmeal, corn meal, cider, cheese, cranberries, onions, dried or salted fish, furs, and woolens, 34° to 36°; for sauerkraut, brined meats, lard, maple syrup, dried fruits, dried corn, peas, beans, etc., 40° to 44°.

Oranges on the trees will stand a temperature of 26° for an hour or so, but if exposed to that temperature for four hours will freeze inside. Oranges slightly frozen, when placed in a cool room and thawed out gradually, are sweetened, and considered by some people as improved, but when frozen solid and thawed they have a sickish sweet

flavor. When oranges have been frozen they can be thawed without injury by putting them in cold water or tight barrels immediately after arrival, and allowing them to thaw out gradually.

The temperature to which lemons, oranges, and bananas may be exposed without damage, varies in different localities, and the different temperatures at those points seem to depend a great deal on the moisture.

Tropical fruits in storage should be kept in rooms with the temperature between 60° and 70°.

While a temperature as low as freezing (32°) will not injure potatoes for eating purposes, yet they will fail to sprout in the spring.

Wines should not be subjected to a temperature lower than 20° or higher than 72°.

Fruit wrapped in heavy brown paper will stand 15° more cold than if not wrapped.

Eastern grapes bear low temperatures better than California or Malaga.

Canned tomatoes when frozen become stringy, canned fish soft and mushy, lemons black and spotted, olives soft and rancid, pickles soft and unsalable.

It appears to be generally conceded that goods, when free from undue dampness, that is, those

classed as dry, will stand a much lower degree of temperature without injury than when moist.

Sauerkraut ferments at 90° and freezes at 15°, either of which conditions spoil it.

All tree seeds, including peach, plum, walnut, etc., sprout better in the spring if frozen during the winter. Bulbs, including tulips, lilies, and hyacinths, are not injured if subjected to a temperature below zero.

Cut flowers will keep three or four days in a temperature a little above freezing.

Fruit should be kept free from decaying matter and filth of all kinds. A spraying apparatus for cleansing choice fruit with water has been found of value. Electric fans for ventilating have been used to advantage. A free exposure to the night air, especially when conditions are favorable for a heavy dew, is conducive to the preservation of both fruit and vegetables.

Oysters in shell can be kept for two months in a dark place when the temperature is but little above freezing if occasionally sprinkled with ice water. Fresh oysters in cans deteriorate after two weeks in any temperature unless frozen.

Fresh fish are stored and shipped in bins with cracked ice, the ice water running over them to

keep them moist. Northern merchants sometimes freeze fish for storage and transportation, but they spoil more quickly after being thawed, and it is claimed that the flavor is injured by freezing. Oysters, if likely to be exposed to very low temperatures, should not be washed.

Temperatures Favorable for Slaughtering Cattle and Hogs and the Preservation and Curing of the Meat.

In the slaughtering of cattle and hogs, and the subsequent curing and preservation of the meat, the temperature of the air and of the dressed meats is an important factor to be considered. Opinions differ somewhat on some points as to the most favorable temperatures for these purposes, but the following are considered reliable:

Animals should never be killed while in an overheated or excited state, but should be kept quiet for twenty-four hours previously and fed lightly on cooling food. Where cold storage rooms are available in which the meat can afterwards be reduced to any required temperature, the killing may be done without injury in any weather; otherwise, a cool, dry day, with the temperature not above 45° or 50°, nor below 20°, is the most favorable. If the weather is wet or damp, the temperature should

not be above 35° or 40°. The killing may be done in warmer weather than this if the temperature on the following night falls to 40°, or below. After killing, the carcasses should be hung without touching each other and allowed to remain for twenty-four hours, or more, until the animal heat has passed off and the temperature is 40°, or less, throughout. Meat thus treated may be shipped or kept for days in a temperature of 45°, or below, in dry weather; 40°, or below, in wet. When the night following the killing is warm, the hind-quarters of beeves are sometimes slit open to allow them to cool more rapidly. Temperatures above 50°, with moist air, damage green meats very quickly. Meat, and particularly pork, that has been frozen and afterwards thawed does not keep as well as that which has been simply chilled. Pork intended for curing should never be frozen.

The following extract from a letter from a Southern state is given as of interest in this connection:

"Cause of Meat Spoiling.—First place, the slaughtering is done during the coldest days and the meat hastily cut up next morning, sometimes a bit frozen, then salted in an outhouse. Now, if several freezing nights come right after the butcher-

ing, the intelligent farmer expresses himself in luck so far as having an ample supply of meat for the coming summer. By and by he thinks it enough time in salt, takes it up, hangs it, and begins the smoking. In about a week he takes the good wife to the smokehouse, shows the plump hams; so far so good. Well, wife cooks one of the hams to see how it is cured; then he finds that he has got a nice lot of gasometers that gives off an odor that the good wife can't tolerate. The trouble is all his own fault. The meat may have frozen through, or at least the salt had frozen, then become caked, and then the action of penetration ceased; but nature does not wait, inside along the bone a gas forms which, if it were just warm enough, the salt would take up and absorb; but, instead, the salt has hermetically sealed it and keeps it in; then the meat takes it up and holds it insoluble until the air can get to it; then decomposition takes place."

It is stated that frozen meat will spoil in sixteen hours if subjected to a temperature of 75°. In the Northwestern States, where the climate is dry, the farmers, between November 15 and February 15, hang green meats in the open air protected from the sun and use from them as occasion requires; meat thus kept is very tender and more palatable

than that fresh killed. Meat hung up in the open air until the animal heat has passed off is said to keep better than that placed in cold storage immediately after being killed, and it is better to follow this method, if practicable, even where cold storage is available. After the animal heat is all out the meat should be put into coolers at a temperature of 50°, and the temperature gradually lowered for forty-eight hours, until it reaches 36°, and then raised slowly to 38°. The principal injury to beef products is stated to occur from sending it from the slaughter house to the chill room before the animal heat has entirely left the carcass; this closes the pores and the meat retains heat and turns sour. From 36° to 42° is the best temperature for storage rooms for dressed meats.

In the case of pork intended for curing, with cold storage available, it is found that a temperature which will reduce the carcass within a period of forty-eight hours to 36°, to 39° at its thickest and most vulnerable points, viz., the centre of the ham and shoulder, is the most desirable. At a temperature of 40° a percentage of taint is liable to develop, and at anything over that temperature tainted meat develops rapidly. Of course it is necessary to create an atmosphere considerably

under these temperatures in order to bring down the temperature of the inside of the carcass at its thickest part to the above figures, and, therefore, it is found desirable to carry the chill rooms at temperatures about 33° to 35°. It is undesirable to reduce the meat to a very low temperature, as its solid and hard condition retards the action of the salt in penetrating to the centre of the piece, and thus causes the process of curing to be slower and less effective. Attaining too low temperatures has been productive of serious loss to curers, as well as failure to obtain sufficiently low temperatures, from the fact that when meat is over-chilled before the curing process begins and taken out after sufficient time has been allowed to thoroughly cure it, were the conditions right, owing to the causes stated, the cure has been retarded, and when exposed to the ordinary atmosphere at warm seasons it becomes spoiled. Some large packers place the hogs after being killed in a temperature of from 45° to 50° for twelve to fifteen hours, and then in a temperature of 35° to 40° for twenty-four to thirty-six hours. According to some experienced authorities the carcasses should not be cut until thoroughly cooled, otherwise the meat is apt to sour. The curing should be done in storage rooms

with the temperature about 40°, the length of time for curing depending on the cut and weight of the meat, and ranging from fifteen to seventy-five days. Storage rooms cooled by the expansion of gases in tubes are considered better than those cooled by ice, on account of being drier. Dry salt pork for southern use in winter needs to be cured in salt for thirty days, but for summer use it should have from fifty to sixty days' curing. Smoked meats for southern use need to be more thoroughly cured than other kinds, as the heating in smoking tends to damage them.

The most favorable conditions for the preservation of green or cured meats for a considerable length of time are found in storage rooms kept at a uniform temperature of from 36° to 40° with a good circulation of dry air.

The Use of the Weather Reports in Connection with the Safe Storage and Shipment of Food Products.

In connection with the storage and shipment of food products liable to injury by heat or cold, much benefit may be derived from an intelligent use of the information contained in the daily weather reports and forecasts published by the

Weather Bureau, which show the temperature conditions prevailing over the whole country at the time of the observations, the highest and lowest temperatures that have occurred during the past twelve hours, and the probable conditions that will prevail during the next twenty-four or thirty-six hours. These reports and forecasts are received at nearly every Weather Bureau office, of which there is one or more in nearly every State and Territory, and published on maps and bulletins, which are posted in conspicuous places in the city where the office is located and mailed to surrounding towns. The reports, or a synopsis of them, are also generally published in the daily papers.

Fuller information than is obtainable from either of these sources may be had at the Weather Bureau office itself from the observer in charge, or, where none of these means are available, arrangements may be made with the observer to supply special information by mail, telephone, or telegraph. In the large cities of the country, dealers in this class of produce are guided in their transactions very largely by the information thus obtained. The temperature of the region to which shipments are to be made is carefully watched and the shipment expedited or delayed according as the con-

ditions are favorable or unfavorable, and shipments on the road are protected from injury by telegraphic instructions as to the necessary precautions to be taken. As shipments in ordinary box cars, or as freight, are less expensive than in refrigerator cars, or by express, advantage is taken of a favorable spell of weather to use the former methods.

In shipping early vegetables north from southern ports the weather reports are utilized to determine whether to use water or railroad transportation, the former being the cheaper. Dealers in certain kinds of produce, by careful attention to the daily weather reports and the weekly crop bulletins, keep themselves informed as to the sections where conditions most favorable for large crops have prevailed, and are thus enabled to judge of the probable supply and to know where to purchase to advantage.

As illustrations of the manner in which advantageous use may be made of the weather reports, suppose a merchant in Ohio has an order in January for a load of apples or potatoes to be shipped to St. Paul; when his shipment is ready he will, if wise, ascertain by personal inquiry at the Weather Bureau office, or by a study of the published reports and forecasts, the probable tem-

perature conditions between Ohio and Minnesota for the period that the shipment is likely to be on the road and will regulate the same accordingly. If neither of these means of information is accessible to him, he may telegraph the observer at the nearest Weather Bureau office, Cincinnati, Columbus, Cleveland, Sandusky, or Toledo, as the case may be, requesting the information, or he may arrange beforehand with the observer to be informed by telegraph when the conditions are favorable for making the shipment, the cost of all telegrams, of course, to be borne by himself. While the consignment is on the road he should still keep himself informed as to the temperature conditions of the region through which it passes, and if injuriously low temperatures are likely to occur, may telegraph to have it housed or otherwise protected until the conditions are again favorable. By the use of similar means, a packer, having a large number of hogs to slaughter may ascertain in advance when temperatures favorable for that purpose are likely to prevail in his locality; or a southern merchant having a consignment of tropical fruit on the road to the north may insure its protection from injuriously high or low temperatures by telegraphic instructions as to the

opening or closing of ventilators, or the use of ice or artificial heat.

During the season when cold waves are liable to occur, a careful watch of the reports and forecasts will often enable dealers and others to protect from injury large quantities of produce in storage. Instances are numerous where the use of the information aforementioned has resulted in large pecuniary benefit.

The lowest and highest temperatures to which perishable goods may be subjected without injury under the conditions stated.

Perishable goods.	Lowest outside temperature.			Temperatures above which injury occurs.	Remarks.
	Articles in ordinary packages unprotected.	In ordinary freight cars.	In refrigerator or specially prepared cars.		
	°	°	°	°	
Apples in bbls. . . .	20	10	—10	75	Covered with straw.
Apples, loose. . . .	28	15	—10	75	Packed in straw.
Apricots, baskets . .	35	24	10	70	
Aqua ammonia, bbls.	30	20	—10	. .	
Asparagus	28	22	. . .	70	In boxes covered with moss.
Bananas	50	32	. . .	90	In bulk and in boxes with straw.
Beans, snap	32	26	. . .	65	In barrels or crates.
Bear	zero.	—20	. . .	65	Shipped loose.
Beer or ale, kegs . .	25	20	zero.	75	Packed in manure and shavings.
Beets	26	20	. . .	70	In crates.

Perishable goods.	Lowest outside temperature.			Temperatures above which injury occurs.	Remarks.
	Articles in ordinary packages unprotected.	In ordinary freight cars.	In refrigerator or specially prepared cars.		
	°	°	°	°	
Bluing	30	20	—10	. .	
Cabbage, early or late	25	20	zero.	75	Barrels or crates.
Cantaloupes	32	25	10	80	
Cauliflower	22	15	. . .	70	In barrels with straw.
Celery	10	zero	. . .	65	Packed in crates.
Cheese	30	25	10	75	
Cider	22	18	—10	70	
Clams, in shell	20	10	—10	65	In barrels.
Cocoanuts	30	20	zero.	90	In barrels or crates.
Crabs	10	zero	. . .	65	In baskets and barrels.
Cranberries	28	20	zero.	. .	
Cucumbers	32	20	. . .	65	In boxes with moss.
Cymlings, or squash.	32	22	. . .	75	In crates.
Deer	zero.	—20	. . .	65	Shipped loose.
Drugs (non-alcoholic)	32	28	zero.	. .	
Eggs, barreled or crated	30	20	zero.	80	
Endive	10	zero	. . .	70	Packed in boxes or crates.
Extracts (flavoring).	20	15	zero.	. .	
Fish	10	zero	. . .	65	In barrels always iced.
Fish, canned	18	15	—10	. .	
Flowers	35	20	—10	. .	Packed in moss.
Grapes	34	20	zero.	.	Packed in cork.
Grape fruit	32	20	zero.	. .	
Groceries, liquid	32	20	zero.	. .	
Ink	20	15	—10	. .	
Kale	15	zero	. . .	65	Packed in boxes or crates.
Leek	28	20	. . .	65	Packed in boxes.
Lemons	32	20	10	75	In boxes or crates.
Lettuce	26	15	. . .	70	In crates or boxes.

Perishable goods.	Lowest outside temperature.			Temperatures above which injury occurs.	Remarks.
	Articles in ordinary packages unprotected.	In ordinary freight cars.	In refrigerator or specially prepared cars.		
	°	°	°	°	
Lobsters	25	20	zero.	. .	
Mandarins	32	20	zero.	75	In boxes.
Medicines, patent. .	32	28	zero.	. .	Packed in sawdust.
Milk	32	28	zero.	75	
Mucilage	25	15	zero.	. .	
Mustard, French . .	26	20	—10		
Okra	25	20	. . .	75	In baskets or boxes.
Olives, in bulk . . .	28	25	zero.	. .	In barrels.
Olives, in glass . . .	25	20	zero.	. .	
Onions, boxes . . .	20	15	zero.	. .	
Onions.	20	10	. . .	80	In barrels, boxes or crates.
Oranges	28	20	zero.	80	In baskets, boxes, barrels or crates.
Oysters, in shell . .	20	10	—10	65	In barrels.
Oysters, shucked . .	30	20	zero.	70	In barrels.
Parsley	32	20	. .	75	In baskets.
Parsnips	32	20	. . .	70	In baskets or barrels.
Partridges.	10	zero	. . .	65	In bunches in boxes.
Paste	32	25	10	. .	In barrels.
Peaches, fresh, baskets	32	20	10	80	
Peaches, canned .	20	15	zero.	.	
Peas	32	20	. . .	80	In baskets or barrels.
Pickles, in bulk . .	22	18	—10	. .	In barrels.
Pickles, in glass . .	20	16	—10	. .	
Pineapples	32	25	zero.	75	In barrels, in crates, or in bulk.
Plums	35	32	zero.	75	In boxes with paper.
Potatoes, Irish . . .	33	25	10	80	In barrels or baskets.
Potatoes, sweet. . .	35	28	10	80	In barrels or baskets.
Radishes	20	15	. . .	65	In baskets.
Rice	20	10	. . .	90	In barrels and sacks.
Shrubs, roses, or trees	35	10	—10	. .	In canvas or sacking.

Perishable goods.	Lowest outside temperature.			Temperatures above which injury occurs.	Remarks.
	Articles in ordinary packages unprotected.	In ordinary freight cars.	In refrigerator or specially prepared cars.		
	°	°	°	°	
Spinach	15	15	. .	75	In barrels or crates.
Strawberries	33	25	—10	65	
Tangerines	25	15	zero.	70	In boxes.
Tea plants	28	20	. . .	95	Packed in boxes.
Thyme	20	10	. . .	90	In small baskets.
Tomatoes, fresh . .	33	28	10	90	
Tomatoes, canned .	28	25	— 5	75	In boxes.
Turnips, late . . .	15	zero	. . .	75	In barrels.
Vinegar, bbls. . . .	22	18	—10	. .	
Watermelons . . .	20	10	. .	85	In barrels and in bulk.
Waters, mineral . .	28	25	zero.	. .	
Wines, light	22	15	zero.	.	
Wild boar	zero.	—20	. . .	65	Shipped loose.
Wild Turkey . . .	zero.	—20	. . .	65	Shipped loose.
Yeast	28	25	zero.	65	

THE TEACHING OF METEOROLOGY IN THE SCHOOLS.—At a meeting of the National Educational Association, held July 9, 1892, a committee of ten was appointed to hold conferences on the study of geography, which included physical geography, geology and meteorology, and consisted of the following gentlemen:—

Prof. Thomas C. Chamberlin, University of Chicago, Chicago, Ill.; Prof. George L. Collic, Belait College, Belait, Wis.; Prof. W. M. Davis,

Harvard University, Cambridge, Mass.; Delwin A. Hamlin, Master of the Rice Training School, Boston, Mass.; Prof. Edwin J. Hanston, Central High School, Philadelphia, Pa.; Prof. M. W. Harrington, Weather Bureau, Washington, D. C.; Charles F. King, Dearborn School, Boston, Mass.; Francis W. Parker, Principal, Cook County Normal School, West Chester, Pa.; Prof. Isaac C. Russell, University of Michigan, Ann Arbor, Mich.

From the extremely and suggestive Report of this Conference on Geography, the following paragraphs in regard to the teaching of meteorology in the schools are taken :—

"Since the establishment of the national Weather Bureau, meteorology has not only been greatly advanced as a systematic science, but it has become a subject of wide popular interest. This, together with its importance as a factor of geography, moves the committee to recommend that meteorology be introduced as an elective study for half a year in the third or fourth year of the high-school course, when practicable. Elementary physics should precede it. It should be opened by local observations of the passing weather changes, accompanied by a study of a series of daily weather maps, and the application of physical principles to

explain the general phenomena of the atmosphere should follow. Local observations should be carried further in this course than they extended in earlier years, especially regarding the sequence of phenomena in the atmosphere and the correlation of various weather elements. The study of weather maps, already familiar objects from the less systematic study of earlier years, should now reach to the clear understanding and description of the distribution of temperature and pressure, flow of the winds, and occurrence of clear, cloudy, rainy or snowy areas, and to a careful induction of generalizations by which various phenomena are connected; for example, the correlation of the direction and velocity of the winds with the value of the barometric gradient; or of areas of high or low pressure with the spiral outflowing or inflowing winds and the areas of clear or cloudy and rainy sky. The effect of the progression of these areas of high and low pressure on local weather changes and their value in weather prediction should be made clear; practical exercises should be given in this connection, as will be more fully explained in a later section. During the advance of local observation and study of the weather maps, instruction should be given on the more general relations of the

science, in which the following headings are the most important: Composition and offices of the atmosphere; arrangement of the atmosphere around the earth under the action of gravity; the nature of solar energy and its distribution over the earth and through the year; the different actions of solar energy on air, land, and water; the mean annual and seasonal distribution of temperature over the earth; the processes of local and general convection; evaporation, humidity, clouds, rainfall; the distribution of atmospheric pressure, and the general circulation of the atmosphere, as modified by the annual march of the sun north and south, and by the influences of the continents; storms, both cyclonic and local; weather changes and their prediction; climate, zones, and their relation to habitation.

"*Methods of Teaching Meteorology.* (*a*) *Intermediate or Grammar School Course.* The simplest facts concerning the weather may be introduced into observational studies as early as the teacher desires. These should be followed by simple instrumental records in the fourth or fifth year, never so complex or frequent as to be burdensome, so that when the sixth and seventh year of school is reached, the scholar will have gained an elementary

but practical and familiar acquaintance with the use of the thermometer, the wind-vane, and the rain-gauge. The barometer and hygrometer should be introduced, if possible, but not so early as the simpler instruments. Habits of punctuality, care, neatness, and system may be taught by keeping a record, and excellent arithmetical practice may be given in determining averages and totals; but the teacher should take care that the scholars' attention be directed to the phenomena of atmospheric changes, as well as to their instrumental records.

"Accompanying the local observation of weather elements, a simple study of weather maps should be introduced; but this should progress very slowly, in order that the best value may be derived from it. The following suggestions may be of service in this connection. Assuming that the school can receive a supply of daily weather maps for at least a part of the school year, and that it has access to maps received in earlier years, let the teacher select several of the older maps on which the winds over the country east of the Rocky Mountains happened to be moving in a systematic manner, for example, a great volume of southerly winds moving northward from the Gulf up the Mississippi valley and inland from the South At-

lantic coast, while westerly winds are advancing across the great plains; or a broad sweep of westerly or northwesterly winds spreading all over the eastern half of the country, as during a cold wave. Draw the wind arrows in heavy black lines, for easier seeing; such work as this may often be entrusted to advantage to some of the better draftsmen among the scholars. In order to enforce the idea that the whole lower part of the atmosphere is moving, and not simply the winds at certain stations of observation, draw many intermediate lines, accordant with the directions of the wind arrows; the length, or heaviness, of these lines may be made to indicate the velocity of the winds. A series of charts may thus be prepared with little trouble, from which an effective presentation of some of the greater facts of meteorology can be easily and clearly made. These maps may be used as the basis of exercises in writing; the description of their wind movements deserves careful statement. When the spiral winds about areas of high pressure and of low pressure are included in the series, the scholars will find all their powers of verbal description called on to enable them to state the facts properly. The continued use of the maps will also serve to impress many geographical facts on the memory.

"Areas of cloud and rainfall may be treated in a similar way; and their contrast with adjacent areas of fair or clear sky afford much material for study and description. The presence of clear weather in one region, while heavy rains are falling in another, is thus taught in a simple and effective manner.

"The distribution of temperature should be introduced, first, by entering the thermometer readings at the various stations on the map in strong figures, so that a class may easily see them; and then asking for verbal statements concerning the warmer and colder parts of the country. By selecting maps in which temperature contrasts are distinct, many interesting exercises may be developed in this manner. When the idea of distribution of warmer and colder areas is gained, it may be suggested that one of the class draw a line to separate all that region which is warmer than 60°, for example, from the region colder than 60°. Similar lines may be drawn by other scholars on other maps. Summer and winter maps may be compared. When the lines are familiar, they may be named 'isotherms.' If the subject is one in which the teacher takes especial interest, and which therefore properly receives more extended treatment than it might otherwise, an additional exercise may

be made on a series of lines at right angles to the isotherms (the lines of temperature-decrease, or the 'thermometric gradient' lines) along which the most rapid decrease of temperature would be experienced. Their trend is generally northward, but on certain occasions their course is peculiarly deformed eastward or westward.

"Barometer readings should be treated in the manner outlined for temperatures. The small difference of their values will soon be noted; and the frequent occurrence of limited oval areas of slightly higher or lower pressure than that of their surroundings will soon attract the attention of the scholars. As with temperature, so here, an examination of the curved lines at right angles to the isobars, along which the pressure decreases, will prove instructive; these lines will converge towards the centre of low pressure areas, and diverge from the centre of high pressure areas. When the isobaric lines are close together, the lines of pressure-decrease should be drawn heavier, to indicate a rapid decrease of pressure. The rapidity of decrease of pressure, as indicated by the closeness of adjacent isobars, should be compared on different maps. When the rate and direction of decrease of pressure can be talked about familiarly it may be

spoken of as 'barometric gradient.' By slow and patient work, even this relatively advanced idea will be grasped by children in the grammar school; but to attain success, it is of the utmost importance that the work should progress no faster than the scholars ask for it by their behavior with the maps. It would be better to have the work thus far outlined extended over occasional exercises for a year than to hasten too fast, making apparent but unreal, substantial progress.

"When examples of winds, temperatures, clouds, rainfall, and pressures have been given in sufficient number, a combination of two elements, as wind and pressure, may be introduced; and here, in particular, the scholars should be given time to discover for themselves the simple relations existing between two such elements. We are persuaded that the error is commonly made, in schools where weather maps are used, of going too fast under the lead of the teacher's brief explanations, perhaps because the teachers themselves are not yet familiar enough with the great lessons that the maps may give; thus not only passing over many matters with insufficient understanding by the scholars, but also preventing the practice in discovery which here develops so great an interest among children

when they are in a properly awakened state, and which gives well-trained scholars so strong an encouragement in their studies. The teacher should supply maps in a proper order, he should guide the advance of the class by judicious questions; but he should leave them to find out the simple meteorological laws, such as those which associate the movement of the winds with the distribution of atmospheric pressure; the variation of temperature with the direction of the winds, etc. In this way, the following principles may be established: The winds flow towards the regions of low pressures, but they generally turn a little to the right of the lines of pressure-decrease, that is, to the right of barometric gradient. The winds blow faster when the pressure decreases rapidly, and calms or light breezes prevail where the pressure is comparatively equable. The winds blow in left-handed curving spirals in areas of low pressure, and in right-handed outward spirals in areas of high pressure, and they are generally stronger in the former than in the latter. Southerly winds cause a rise of temperature; northerly winds cause a fall of temperature. Areas of low pressure are generally cloudy, with rain in summer, and with rain and snow in winter; areas of high pressure are prevailingly clear with

warm days and cool nights in summer, and with cold weather and extremely cold nights in winter. These areas move in a general eastward course over the country, carrying their changes of wind and weather with them, in such a manner that the stationary observer suffers changes from clear to cloudy weather, and from warm southerly to cool northerly or westerly winds as they pass. Thunder-storms of summer time generally occur in the southeastern quadrant of low pressure areas.

"During the advance of this work, current weather maps may be introduced to give exercise on the problems in hand, whenever they serve the purpose well. A connection may thus be made between the local weather noted at the school and the general atmospheric conditions over the country; and a passing rainstorm, or a strong change of temperature, may be thus traced with great interest and profit. All through the work, continual practice should be maintained in formulating and writing the conclusions reached by study. As the study advances, these written records become, in effect, so many compact generalizations in which the scholars' inductions are preserved. The training of mental powers and the encouragement given to persevering and intelligent study are not among

the least of the results gained from work of this kind.

"Without going further through an account of elementary exercises, based on the weather map and illustrated by local weather observations, we may add a few examples of subjects that may be borrowed from meteorology for the aid of descriptive geography. The prevalence of westerly winds, and the general advance of areas of high and low pressure from west to east, may be mentioned as one of the strongest characteristics of the middle temperate zone; and in contrast, the oblique northeast and southeast trade winds, blowing steadily, with few stormy interruptions, may be instanced as a prevailing characteristic of the torrid zone. The greater intensity of weather changes may be pointed out as a feature of winter, when we experience something of frigid conditions; the less intensity of weather change is a feature of summer, when we are visited by almost torrid heat. The general increase of rain or snow within areas of low pressure, as they approach the Atlantic coast, may be used to explain the aridity of our western interior region, and of other continental interiors. The smaller variations of temperature near the coast, and particularly on the Pacific coast, than in

the upper Mississippi valley, may be employed to teach one of the greatest climatic contrasts of the world.

"(*b*) *High School Course.* The course in meteorology in the high school should be directed quite as much towards a training in the methods of logical investigation, as towards imparting information concerning the science. It should not be attempted until after a course in physics is passed. For the sake of brevity, only the shortest outline of the work can be introduced.

"Facts of local observation about the school and of extended observation through the weather maps bring almost continuous but variable movements of the atmosphere before the class. The correlations discovered from the weather maps in the grammar school, now reviewed, show a clear connection between the movement of the winds and a variety of the other weather elements. Let it, therefore, be suggested that the cause of the winds be the main line of study, leaving the associated phenomena to be examined and explained in their natural connection with the winds.

"Recalling the teaching of physics, it appears that no cause for atmospheric movement is so available as convection, that is, a gravitative circulatory

movement excited by differences of temperature. Under assumed conditions as to temperature, the resulting distribution of atmospheric pressure and flow of the winds may be deduced in accordance with accepted physical principles, and this process may be at once contrasted with the inductive process by which the correlations of the weather maps were established. It may be then stated that if the distribution of temperature over the earth were known, the general circulation of the winds and the distribution of pressure could be predicted, and, according to the closeness of agreement afterwards found between these predictions and the facts, the theory of the convectional cause of the winds would be accepted or rejected, thus introducing the class to a rational method of scientific investigation, applicable in all manner of studies, as well as in meteorology.

"On perceiving the direction thus given to further inquiry, the study of the control and distribution of atmospheric temperature is naturally taken up, because it is manifestly needed before further advance can be made. Under this division of the subject, the teacher is advised to make clear the distinction between radiant solar energy, which traverses the celestial spaces in all directions

from the sun, and of which a very small part reaches the earth, and the heat produced when this energy is acquired or absorbed by terrestrial matter. Interesting illustrations of physical processes are found in this connection; the different rates of absorption of radiant energy by air, water, and land, the control of temperature by specific heat, latent heat, dynamic cooling of ascending air currents, etc., etc.

"The distribution of temperature on annual and seasonal isothermal charts may next be studied, noting the prevailingly high and uniform temperatures of the torrid zone, the variable temperature of the temperate zone, and the prevailingly low temperatures of the frigid zones; noting also the small variations of temperature from season to season on the oceans, even in relatively high latitudes, while the lands of the temperate zone have extremely variable temperatures.

"In accordance with the theory of convectional circulation, it is now possible to predict the distribution of pressure, and the flow of the winds, on the assumption that they are entirely the product of differences of temperature maintained by the sun. The predictions should be carefully formulated and entered on a blank map of the world. A

series of annual and seasonal charts of pressures and winds should then be compared with the predicted consequences of the theory. It will be apparent that the theory is incomplete, because there are many differences between its predicted consequences and the facts; but all these differences are explained when adequate account is taken of the effect of the earth's rotation in deflecting the winds from the gradients and in rearranging the distribution of pressures. A good understanding of the general circulation of the atmosphere and its seasonal variations may thus be gained. Both the value and the danger of the deductive method, and the importance of continually confronting the consequences deduced from theory with the results of observation may be impressed by this lesson.

"On attaining a rational understanding of the prevailing winds of the world, the consideration of atmospheric moisture and clouds may be introduced before the study of storms and rainfall is approached. In connection with the formation of clouds, the effects of the liberation of latent heat during the condensation of vapor should be deliberately examined, as a matter of much importance in the larger processes of convection.

"Tropical cyclones offer the best introduction to

the study of the stormy interruptions of the general circulation of the atmosphere. These cyclones are well-defined phenomena, closely studied in certain tropical seas, and of serious importance as dangers to navigation. The place and season of their origin and the manner of their action point to the conclusion that they are violent convectional whirls, turning in consequence of the earth's rotation, and supplied with much of their energy from the latent heat of the vapor that is condensed to furnish their heavy rains. They exhibit in a small way many features already familiar in the general circulation of the atmosphere around the poles. On coming next to cyclonic storms, and the anti-cyclonic areas of temperate latitudes, which together constitute the regions of low and high pressure in our weather maps, the presumption that they are convectional phenomena is naturally conceived, because convection has been previously found to be so sufficient a cause of the general circulation of the atmosphere and of tropical cyclones; but on perceiving that our cyclones and anti-cyclones are more frequent and more violent in winter than in summer, their convectional origin cannot be taken for granted, and other causes for their action must be examined. The science of meteorology is at present undecided

on this question; although the weight of evidence leans towards explaining the cyclones and anti-cyclones of the temperate zones as an effect of irregular movements in the general circulation, rather than as independent, spontaneous, convectional phenomena. The absence of a demonstrated settlement of this question is not held to be good reason for excluding the discussion of the causes of these most interesting and important phenomena from the range of high school study. Students should as carefully learn to hold open opinions on disputed subjects as they are led to believe firmly in the demonstrable propositions of geometry. In all argumentative studies, the evidence leading to the conclusions, and not simply the conclusions, should receive careful consideration.

"The cyclones and anti-cyclones of our latitudes are found of great importance not only in explaining the changes of weather—as has already been made familiar from earlier study—but also in the determination of the occurrence of local thunderstorms and tornadoes; for these are determined for the most part by instability produced by the importation of warm and cold currents about the areas of low and high pressure.

"The distribution of rainfall is best introduced

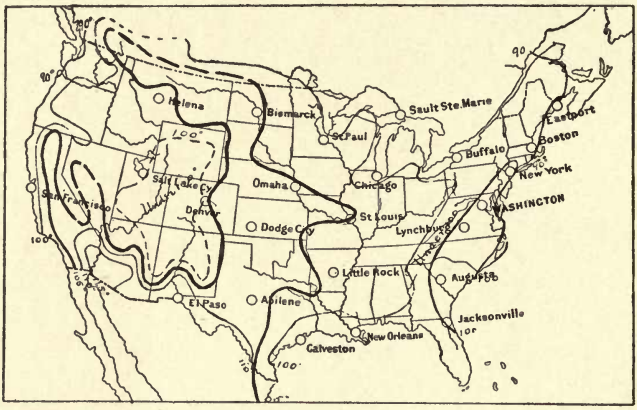
after the explanation of winds and storms, both general and local. It may be used in confirmation of the explanations already given of the winds—the migrating equatorial rains of the doldrums; the dry belts of the trade winds, except where they blow against mountains; the stormy rains of the westerly winds in temperate and higher latitudes; the subtropical winter rains—all these follow as corollaries of the movements already recognized.

"A general review of the subject may be made under the heading of climate, where the various phenomena hitherto studied separately may now be grouped geographically, and considered especially with regard to their influence on the development of organic life, and on the habitation of various regions by man."

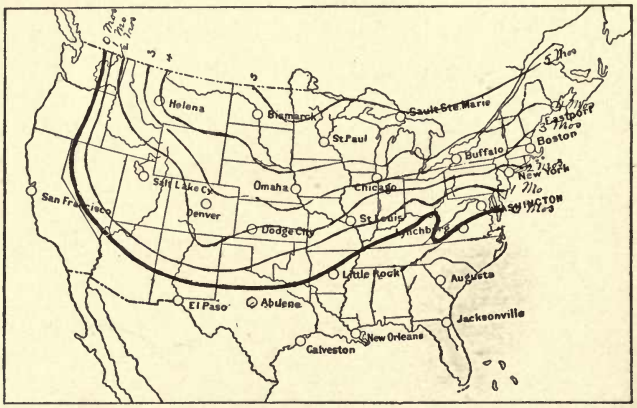
THE MIDNIGHT SUN.—Frequent inquiries have been made relative to the time when and in what part of the world the midnight sun is to be seen. For the benefit of those interested it is inserted in this work. Spring commences with the vernal equinox and lasts till the summer solsticen, then follows summer till the autumnal equinox, then autumn till the winter solstice and winter till the vernal equinox. In northern latitudes between the vernal and autumnal equinoxes, because of

the inclination of the earth's north pole towards the sun, a portion of the earth's surface nearest to that pole remains as the earth revolves, constantly within the light of the sun, so that for a certain period of time (at the pole itself, six months) the sun does not set and the phenomenon of the midnight sun then occurs.

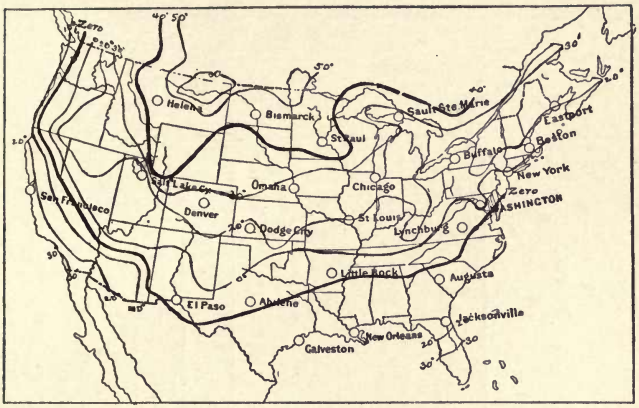
At Spitzbergen (lying between 76° 30′ and 80° 30′ north latitude) the midnight sun may be seen for four months of the year, from the end of April until late in August. From the autumnal to the vernal equinox, those parts of the earth nearest the north pole have a period of continual darkness, varying with the distance from the pole, while the phenomenon of the midnight sun is then repeated at the south pole.



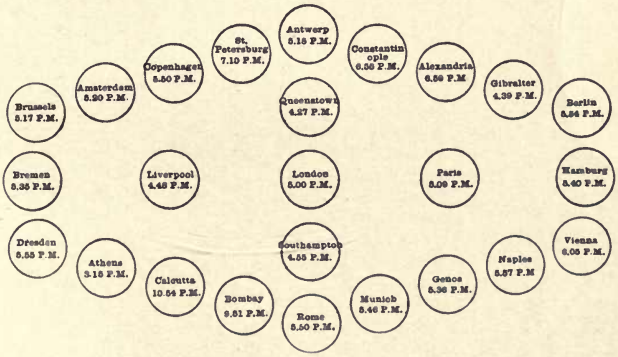
Outline map showing maximum temperatures in districts. Extreme temperatures it will be observed are confined within the heavy lines in the western states and range from 105 to 110 degrees; except in Arizona there is an enclosure of 115 degrees.



The number of months the average daily mean temperature remains below freezing point or 32 degrees is shown by figures at end of lines. South and west of the heavy line the average daily mean temperature is above freezing point throughout the year.



Lines of minimum temperatures. All north of the zero line the temperatures touch below zero according to figures at end of each line respectively. It will be observed that freezing temperatures are recorded in all parts of the United States, except the southern end of the peninsula of Florida.



Local mean time when it is 12 o'clock noon at New York City.

Normal Temperature and Rainfall in the United States,

AT WEATHER BUREAU STATIONS, ALSO HIGHEST AND LOWEST TEMPERATURES EVER REPORTED.

States and Territories.	Stations.	Temperature. Mean Jan.	Temperature. Mean July.	Temperature. Extremes Highest.	Temperature. Extremes Lowest.	Mean Annual Precipitation, Rain and Melted Snow (in.)
Ala.	Mobile	50	82	101	— 1	62.2
	Montgomery	48	82	107	— 5	52.7
Ariz.	Yuma	54	92	118	22	3.0
Ark.	Fort Smith	34	80	107	—15	44.7
	Little Rock	40	81	105	—12	53.6
Cal.	Red Bluff	46	82	114	18	26.1
	Sacramento	46	72	110	19	20.9
	San Diego	54	67	101	32	10.5
Colo.	Denver	27	72	105	—29	14.5
Conn.	New Haven	27	72	100	—14	50.3
Del.	Del. Br'kwater	33	73	93	1	32.6
Dist. of Col.	Washington	33	77	104	—15	43.5
Florida	Jacksonville	55	82	104	10	54.1
	Key West	70	84	100	41	38.5
Georgia	Atlanta	43	78	100	— 8	52.0
	Savannah	51	82	105	8	51.9
Idaho	Boise	28	73	107	—28	13.2
Illinois	Chicago	24	72	100	—23	34.8
	Springfield	25	77	102	—22	38.0
Indiana	Indianapolis	28	76	101	—25	43.0
Ind. Ter.	Sill, Fort	35	82	107	— 9	31.2
Iowa	Des Moines	17	75	104	—30	33.1
	Keokuk	23	77	104	—24	34.7
Kansas	Dodge	25	78	108	—26	19.8

States and Territories.	Stations.	Temperature. Mean Jan.	Temperature. Mean July.	Temperature. Extremes Highest.	Temperature. Extremes Lowest.	Mean Annual Precipitation. Rain and Melted Snow (in.)
Ky.	Louisville	34	79	105	—20	45.8
La.	New Orleans	54	83	99	7	60.5
	Shreveport	45	83	107	— 5	48.6
Maine	Eastport	20	60	91	—21	45.2
	Portland	23	69	97	—17	42.3
Md.	Baltimore	34	78	104	— 7	43.8
Mass.	Boston	26	71	101	—13	45.0
Mich.	Marquette	16	65	100	—27	32.4
	Port Huron	21	69	99	—25	31.6
Minn.	Duluth	10	66	99	—41	31.0
	St. Paul	11	72	100	—41	27.5
Miss.	Vicksburg	47	82	101	— 1	55.7
Mo.	St. Louis	30	79	106	—22	41.1
	Springfield	32	75	102	—29	45.7
Mon.	Havre	9	67	108	—55	14.1
Neb.	Omaha	19	76	106	—32	31.7
	Valentine	14	74	106	—38	19.1
Nevada	Winnemucca	28	72	104	—28	8.5
N. C.	Hatteras	44	78	92	8	66.4
	Wilmington	47	80	103	5	54.3
N. Dak.	Bismarck	4	67	105	—44	18.4
	Williston	3	68	107	—49	14.0
N. H.	Manchester	22	69	96	—11	41 9
N. J.	Cape May	34	74	91	— 3	47.2
	New Brunswick	28	74	100	—10	46.8
N. Mex.	Santa Fe	28	68	97	—13	14.2
N. Y.	Albany	23	73	100	—18	37.9
	New York City	30	74	100	— 6	44.8
	Oswego	25	69	100	—23	35.0
Ohio	Cincinnati	33	78	104	—17	39.9
	Toledo	26	74	99	—16	30.9

States and Territories.	Stations.	Temperature. Mean Jan.	Temperature. Mean July.	Temperature. Extremes Highest.	Temperature. Extremes Lowest.	Mean Annual Precipitation. Rain and Melted Snow (in.)
Oregon	Portland	39	67	102	— 2	46.8
	Roseburg	40	66	104	— 6	35.2
Pa.	Philadelphia	32	76	102	— 6	39.8
	Pittsburgh	30	74	103	—20	36.7
R. I.	Newport	30	70	92	— 8	50.0
S. C.	Charleston	49	82	104	7	56.7
S. Dak.	Yankton	13	74	103	—34	26.8
Tenn.	Memphis	40	81	102	— 9	53.3
	Nashville	38	80	104	—13	50.1
Texas	El Paso	44	82	113	— 5	9.3
	Palestine	43	82	104	— 6	46.5
Utah	Salt Lake	28	76	102	—20	16.2
Vt.	Burlington	19	71	97	—25	28.8
Va.	Lynchburg	36	78	102	— 6	42.8
	Norfolk	40	79	102	2	52.1
Wash.	Dayton	30	68	109	—26	27.8
	Olympia	38	62	97	— 2	53.1
W. Va.	Morgantown	35	74	97	—25	46.9
Wis.	La Crosse	15	73	101	—43	30.7
	Milwaukee	19	69	100	—25	32.1
Wyo.	Cheyenne	25	67	100	—38	12.2

The minus (—) sign indicates temperature below zero.

WET AND DRY BULB HYGROMETER TABLE.

Reading of Dry Thermometer	Difference Between Dry and Wet Thermometers.														
	1.0°	2.0°	3.0°	4.0°	5.0°	6.0°	7.0°	8.0°	9.0°	10.0°	11.0°	12.0°	13.0°	14.0°	15.0°
	Amount to be subtracted from the Wet Thermometers to obtain the Dew-Point.														
30°	3.2°	6.3°	9.5°	12.6°	15.8°	18.9°	22.1°	25.2°	28.4°	31.5°	34.7°	37.8°	41.0°	44.1°	47.3°
31	2.7	5.4	8.1	10.8	13.5	16.2	18.9	21.6	24.3	27.0	29.7	32.4	35.1	37.8	40.5
32	2.3	4.6	7.0	9.3	11.6	13.9	16.2	18.6	20.9	23.2	25.5	27.8	30.2	32.5	34.8
33	2.0	4.0	6.0	8.0	10.0	12.1	14.1	16.1	18.1	20.1	22.1	24.1	26.1	28.1	30.2
34	1.8	3.5	5.3	7.1	8.9	10.6	12.4	14.2	15.9	17.7	19.5	21.2	23.0	24.8	26.6
35	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	20.8	22.4	24.0
36	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	21.0	22.5
37	1.4	2.8	4.3	5.7	7.1	8.5	9.9	11.4	12.8	14.2	15.6	17.0	18.5	19.9	21.3
38	1.4	2.7	4.1	5.4	6.8	8.2	9.5	10.9	12.2	13.6	15.0	16.3	17.7	19.0	20.4
39	1.3	2.6	4.0	5.3	6.6	7.9	9.2	10.6	11.9	13.2	14.5	15.8	17.2	18.5	19.8
40	1.3	2.6	3.9	5.2	6.5	7.7	9.0	10.3	11.6	12.9	14.2	15.5	16.8	18.1	19.4
41	1.3	2.5	3.8	5.0	6.3	7.6	8.8	10.1	11.3	12.6	13.9	15.1	16.4	17.6	18.9
42	1.2	2.5	3.7	4.9	6.2	7.4	8.6	9.8	11.1	12.3	13.5	14.8	16.0	17.2	18.5
43	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0
44	1.2	2.4	3.5	4.7	5.9	7.1	8.3	9.4	10.6	11.8	13.0	14.2	15.3	16.5	17.7
45	1.2	2.3	3.5	4.6	5.8	7.0	8.1	9.3	10.4	11.6	12.8	13.9	15.1	16.2	17.4
46	1.1	2.3	3.4	4.6	5.7	6.8	8.0	9.1	10.3	11.4	12.5	13.7	14.8	16.0	17.1
47	1.1	2.2	3.4	4.5	5.6	6.7	7.8	9.0	10.1	11.2	12.3	13.4	14.6	15.7	16.8
48	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	14.3	15.4	16.5
49	1.1	2.2	3.2	4.3	5.4	6.5	7.6	8.6	9.7	10.8	11.9	13.0	14.0	15.1	16.2
50	1.1	2.1	3.2	4.2	5.3	6.4	7.4	8.5	9.5	10.6	11.7	12.7	13.8	14.8	15.9
51	1.0	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.4	10.4	11.4	12.5	13.5	14.6	15.6
52	1.0	2.0	3.1	4.1	5.1	6.1	7.1	8.2	9.2	10.2	11.2	12.2	13.3	14.3	15.3
53	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
54	1.0	2.0	2.9	3.9	4.9	5.9	6.9	7.8	8.8	9.8	10.8	11.8	12.7	13.7	14.7
55	1.0	1.9	2.9	3.8	4.8	5.8	6.7	7.7	8.6	9.6	10.6	11.5	12.5	13.4	14.4
56	0.9	1.9	2.8	3.8	4.7	5.6	6.6	7.5	8.5	9.4	10.3	11.3	12.2	13.2	14.1
57	0.9	1.8	2.8	3.7	4.6	5.5	6.4	7.4	8.3	9.2	10.1	11.0	12.0	12.9	13.8
58	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0	9.9	10.8	11.7	12.6	13.5
59	0.9	1.8	2.7	3.6	4.5	5.3	6.2	7.1	8.0	8.9	9.8	10.7	11.6	12.5	13.4
60	0.9	1.8	2.6	3.5	4.4	5.3	6.2	7.0	7.9	8.8	9.7	10.6	11.4	12.3	13.2
61	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.8	8.7	9.6	10.4	11.3	12.2	13.1
62	0.9	1.7	2.6	3.4	4.3	5.2	6.0	6.9	7.7	8.6	9.5	10.3	11.2	12.0	12.9
63	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5	9.4	10.2	11.1	11.9	12.8
64	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.6	7.5	8.3	9.1	10.0	10.8	11.6	12.5
65	0.8	1.6	2.5	3.3	4.1	4.9	5.7	6.6	7.4	8.2	9.0	9.8	10.7	11.5	12.3
66	0.8	1.6	2.4	3.2	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7	10.5	11.3	12.2
67	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.4	11.2	12.0
68	0.8	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.1	11.9
69	0.8	1.6	2.3	3.1	3.9	4.7	5.5	6.2	7.0	7.8	8.6	9.4	10.1	10.9	11.7
70	0.8	1.5	2.3	3.1	3.9	4.6	5.4	6.2	6.9	7.7	8.5	9.2	10.0	10.8	11.6
71	0.8	1.5	2.3	3.0	3.8	4.6	5.3	6.1	6.8	7.6	8.4	9.1	9.9	10.6	11.4
72	0.8	1.5	2.3	3.0	3.8	4.5	5.3	6.0	6.8	7.5	8.3	9.0	9.8	10.5	11.3
73	0.7	1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	7.4	8.1	8.9	9.6	10.4	11.1
74	0.7	1.5	2.2	2.9	3.7	4.4	5.1	5.8	6.6	7.3	8.0	8.8	9.5	10.2	11.0
75	0.7	1.4	2.2	2.9	3.6	4.3	5.0	5.8	6.5	7.2	7.9	8.6	9.4	10.1	10.8
76	0.7	1.4	2.1	2.8	3.6	4.3	5.0	5.7	6.4	7.1	7.8	8.5	9.2	9.9	10.7
77	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	7.7	8.4	9.1	9.8	10.5
78	0.7	1.4	2.1	2.8	3.5	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	9.7	10.4
79	0.7	1.4	2.1	2.8	3.5	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	9.7	10.4

SHOWING DEPTH OF PRECIPITATION CORRESPONDING TO GIVEN WEIGHTS.

(Computed for 8-inch circular collector; water at maximum density: 39° Fahr.)

Weights.		Rainfall (inches).				Weights.		Rainfall (inches).			
lbs.	oz.	0 oz.	¼ oz.	½ oz.	¾ oz.	lbs.	oz.	0 oz.	¼ oz.	½ oz.	¾ oz.
	0	.00	.01	.02	.03	2	12	1.51	1.52	1.53	1.54
	1	.03	.04	.05	.06	2	13	1.55	1.56	1.57	1.57
	2	.07	.08	.09	.09	2	14	1.58	1.59	1.60	1 61
	3	.10	.11	.12	.13	2	15	1.62	1.63	1.63	1.64
	4	.14	.15	.15	.16	3	0	1.65	1.66	1.67	1.68
	5	.17	.18	.19	.20	3	1	1.69	1.69	1.70	1.71
	6	.21	.22	.22	.23	3	2	1.72	1.73	1.74	1.75
	7	.24	.25	.26	.27	3	3	1.75	1.76	1.77	1.78
	8	.28	.28	.29	.30	3	4	1.79	1.80	1.81	1.81
	9	.31	.32	.33	.34	3	5	1.82	1.83	1.84	1.85
	10	.34	.35	.36	.37	3	6	1.86	1.87	1.87	1.88
	11	.38	.39	.40	.41	3	7	1.89	1.90	1.91	1.92
	12	.41	.42	.43	.44	3	8	1.93	1.94	1.94	1.95
	13	.45	.46	.46	.47	3	9	1.96	1.97	1.98	1.99
	14	.48	.49	.50	.51	3	10	2.00	2.00	2.01	2.02
	15	.52	.52	.53	.54	3	11	2.03	2.04	2.05	2.06
1	0	.55	.56	.57	.58	3	12	2.06	2.07	2.08	2.09
1	1	.58	.59	.60	.61	3	13	2.10	2.11	2.12	2.12
1	2	.62	.63	.64	.65	3	14	2.13	2.14	2.15	2.16
1	3	.65	.66	.67	.68	3	15	2.17	2.18	2.18	2.19
1	4	.69	.70	.71	.71	4	0	2.20	2.21	2.22	2.23
1	5	.72	.73	.74	.75	4	1	2.24	2.24	2.25	2.26
1	6	.76	.77	.77	.78	4	2	2.27	2.28	2.29	2.30
1	7	.79	.80	.81	.82	4	3	2.30	2.31	2.32	2.33
1	8	.83	.83	.84	.85	4	4	2.34	2.35	2.36	2.37
1	9	.86	.87	.88	.89	4	5	2.37	2.38	2.39	2.40
1	10	.89	.90	.91	.92	4	6	2.41	2.42	2.43	2.43
1	11	.93	.94	.94	.95	4	7	2.44	2.45	2.46	2.47
1	12	.96	.97	.98	.99	4	8	2.48	2.49	2.49	2.50
1	13	1.00	1.01	1.01	1.02	4	9	2.51	2.52	2.53	2.54
1	14	1.03	1.04	1.05	1.06	4	10	2 55	2.56	2.56	2.57
1	15	1.07	1.08	1.08	1.09	4	11	2.58	2.59	2.60	2.61
2	0	1.10	1.11	1.12	1.13	4	12	2.61	2.62	2.63	2.64
2	1	1.14	1.14	1.15	1.16	4	13	2.65	2.66	2.67	2.67
2	2	1.17	1.18	1.19	1.20	4	14	2.68	2.69	2.70	2.71
2	3	1.20	1.21	1.22	1.23	4	15	2.72	2.73	2.73	2.74
2	4	1.24	1.25	1.26	1.26	5	0	2.75	2.76	2 77	2.78
2	5	1.27	1.28	1.29	1.30	5	1	2.79	2.80	2.80	2.81
2	6	1.31	1.32	1.32	1.33	5	2	2.82	2.83	2.84	2 85
2	7	1.34	1.35	1.36	1.37	5	3	2 86	2.86	2 87	2.88
2	8	1.38	1.38	1.39	1.40	5	4	2.89	2.90	2.91	2.92
2	9	1.41	1.42	1.43	1.44	5	5	2.92	2.93	2.94	2.95
2	10	1.44	1.45	1.46	1.47	5	6	2.96	2.97	2.98	2.98
2	11	1.48	1.49	1.50	1.51	5	7	2.99	3.00	3.01	3.02

TIDE TABLE

Showing the differences between the time of High Water at New York and the following places. The hours and minutes standing against the place in this table are to be added to or subtracted from the time of High Water at New York on any given day, which will give (nearly) the time of High Water at the following places:

	H. M.	F*		H. M.	F*
Amboy, N. J. . .	—0.45	5.0	Lynn Harbor, Mass.	+3.05	9.0
Annapolis, Md. . .	—3.29	1.0	Machias, Me. . . .	+2.40	12.9
Baltimore, Md. . .	—1.34	1.0	Marblehead, Mass.	+3.10	10.0
Barnegat Inlet, N. J.	—0.09	2.3	Montauk Point . .	+0.02	2.5
Boston, Mass. (City).	+3.20	11.0	Navy Yard, B'klyn.	+0.47	4.4
Block Island, R. I.	—0.42	3.0	Nantucket, Mass. .	+4.03	3.0
Bridgeport, Conn. .	+2.51	6.0	Nahant, Mass. .	+3.02	9.1
Boston Light. . . .	+3.03	9.0	New'k By(N.J.)L.H	+0.32	4.8
Cold Sp'g Inlet, N.J.	—0.48	5.0	New Bedford, Mass.	—0.15	4.0
Cape May, N. J. .	+0.10	5.0	Newburyport, Mass.	+3.02	8.0
Cape May Ld'g, N. J.	+0.12	4.8	Newport, R. I. . .	—0.30	4.0
Cape Ann, Mass. .	+3.04	11.0	New London, Conn.	+1.12	3.0
Cape Cod, Mass. .	+3.09	6.0	New Haven, Conn.	+3.05	6.0
Cape Henry, Va. .	—0.40	4.0	Norfolk N'y Y'd, Va	+1.06	3.1
Cape Henlopen, Del.	+0.20	4.0	Old Point Comfort.	+0.42	3.0
Cape Hatteras, N.C.	+0.40	5.0	Philadelphia, Pa, .	+4.58	6.0
City Point, Va. . .	+6.29	2.8	Plymouth, Mass. .	+3.10	6.0
Cuttyhunk, Mass. .	—0.27	3.6	Portland, Me. . .	+3 05	10.0
Delaware (B'kwater)	—0.10	3.5	Portsmouth, N H.	+3.10	10.0
Elizabeth Point, N.J	+0.34	5.0	Point Judith, R. I.	—0 45	4.0
Edgartown, Mass. .	+3.56	2.0	Point Lookout, Md.	+4.38	1.0
Egg I'd Light, N.J.	+0.44	6.0	Providence, R. I. .	+0.07	5.0
Fairfield, Conn. . .	+2.40	6.0	Salem, Mass. . . .	+2.46	11 0
Fire Island Inlet. .	—0.52	2.1	Sands Point, N. Y.	+2.53	9.0
Gloucester, Mass. .	+2.40	9.0	Sandy Hook, N. J.	—0.39	5.0
Gay Head, Mass. .	—0.41	7.0	Savannah (DD'k) Ga	+0.05	7.0
Greenwich, R. I. .	—0.05	4.6	Saybrook, Conn. .	+2.15	4.0
Hallet's Cove, L. I.	+1.52	5.3	St. John's River, Fla	—0.49	5.0
Hatteras Inlet, N.C.	—1.16	2.0	Stonington, Conn. .	+0.47	3 0
Hell Gate, N. Y. .	+1.49	5.0	Tarrytown, N. Y. .	+1.37	4.0
Holmes' Hole, Mass.	+3.23	2.0	Ward's Island . .	+2.07	5.0
Huntington, N. Y.	+2.40	5.0	Warren, R. I. .	—0.02	4.7
Keyport, N. J. . .	—0.34	3.8	Watch Hill, R. I. .	+0.40	3.0
Little Egg H'b'r, N.J	—0.57	4.0	Woods Hole, Mass.	—0.08	4.1
Little Gull I'd, L. I.	+1.31	2.6			

+ Signifies add. — Signifies subtract. * This column shows the vertical rise of the Tides in feet.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

Index

AIR, a refracting medium, 98
" composition of, 1
" circulation of, 2, 3
" decomposed, 7
" dry, proportion of, 1
" dust in, 7, 8
" impurities of, 7
" inequality of, 100
" motion of, 53, 54
" pounds per square inch, 3
" pressure, 3, 9
" " annual change, 18
" " daily change, 18
" " at sea level, 9
" rarified, 8, 37
" transparency of, 68, 99, 100
Algeria, 46
Anemometer, 31, 32, 33
Anti-cyclone, features of, 124 to 130
Anti-trade winds, 55, 56
Areas of low pressure, birthplace, 123
Areas of high pressure or anticyclones, 124, 125
Areas of low pressure paths, 122, 123
Areas of low pressure, 112, 113
Areas of low pressure, description of, 112, 113
Atmosphere, a shield, 42
" capacity of, 66
" density of, 2
Atmosphere, greatest capacity, 67
Atmosphere, height of, 2
" how heated, 41
" weight of, 2
Atmospheric electricity, 105 to 109
Aurora australis, 108, 109
" borealis, 108, 109
Autumnal equinox, 40

BAROMETER, 10 to 19, 179
Barometer, adjusting screw, 12
" aneroid, 13, 14
" " how to set, 18
Barometer, construction of, 13
" correction for elevation, 17, 18
Barometer, engineers' and tourists', 16
Barometer, exterior, 14
" fluctuations of, 19, 179
Barometer, forecasting by, 237 to 264
Barometer, how made, 10, 11
" measurement of heights, 15, 16, 17
Barometer, scale, 12
" tube, 10, 17
" uses of, 14, 15
Belt of calms, 55
Blizzards, 59
Breezes, ocean, 56, 57

CALMS, belt of, 55

California, hot winds of, 59
Carbon-dioxide, 1
Chinook, winds, 58
Climate, 194 to 237
" action of altitude on diseases of chest, 203 to 218
Climate, altitude and hay fever, 232 to 237
Climate, changes of, 200, 201
" causative elements, 219, 220
Climate, dry and moist, 202, 203
Climate, dry and cool air, 223
" influence of winds on, 198, 199
Climate, mountain and sea air, 231, 232
Climate, preventive and curative elements, 219
Climate, principal elements, 196, 197
Climate, range of, 200
Climate, sea cost or oceanic, 197, 198
Climate, selecting of, 199, 200
" the atmosphere and pulmonary hemorrhage, 218
Climate, treatment of phthisis pulmonalis, 220 to 223
Cloudbursts, 86, 87
Cloud formation, 73
" shadows, 76
Cloudiness, amount of, 76
" least, 76, 77
" over U. S., 77
Clouds, 73
" cirro-cumulus, 74
" cirro stratus, 74
" cirrus, 74
" classification of, 73
" color of, 101
" cumulus, 75, 76
" evening, 101
" lower, 74
" morning, 101
" nimbus, 75
Clouds, preceding cyclones, 118
" strato-cumulus, 75
" stratus, 76
" upper, 74
Cloudy days, 8
Cold, in southern latitudes, 184
" waves, 180 to 187
" " centre of, 183
" " change of temperature with change of high pressure centre, 186
Cold waves, crest of, 182, 183
" " extent of, 185, 186
" " forecasting of, 181 to 187
Cold waves, frequency of, 185
" " influence of low pressure on, 184, 185
Cold waves, path of, 181, 182
" " precipitation, 186, 187
Cold waves, rate of progress, 186
Cold waves, when move south, 183
Condensation, 69, 70
Coronas, 109, 110
" how caused, 109
Cyclones, 111 to 113
" anti or areas of high pressure, 124, 125
Cyclones, birthplace of, 123
" deflected, 121, 122
" diameter and shape of, 120, 121
Cyclones, eliptical shape, 120, 121
Cyclones, force of, 119
" movement of, 118
" outline of, 117
" progressive movement, 119, 120
Cyclones, propagation of, 121
" rain attending, 121, 122
Cyclones, rapid movement, 120, 121

Cyclones, rotary movement, 119, 120
Cyclones, temperature attending, 117
Cyclonic centre, 116
" features, 113
" paths, 122, 123
" system, 112

DAKOTA, NORTH, 45
Day, longest, 40
" shortest, 40
" warmest part of, 41
Death valley, 45
Dew, 92, 93
" in California, 93
" conditions for, 93
" deposit, 93
" formation of, 92, 93
" heaviest, 93
" prevention of, 93
Distance observable, 8
Dust in air, 7, 8
" particles, 100

EARTH, friction on storms, 120
Electrical conductors good and bad, 106, 107
Electrical discharge, 106
Electricity, atmospheric, 105 to 109
Equinox, autumnal, 40
" vernal, 40
Evaporation, 63, 64
" amount of, 64
" at all times, 63, 64
" cause of, 63
" measurement of, 65

FIRE, St. Elmo's, 108
Fog, 70, 101, 102
" dry, 72
" frequency of, 71, 72
" how caused, 71, 72
" thickness of, 72
Fohn-winds, 57, 58

Food products in storage, 304 to 320
Forecasting by barometer, clouds, winds, sunrise, sunset, and all local conditions, 237 to 283
Forecasting by polymeter, 279 to 283
Forecasting practical, by weather maps, 159 to 194
Frost, average time of first killing of autumn, 95, 96
Frost, average time of last killing of spring, 96
Frost, conditions favorable for, 187, 188
Frost, damage to corn and wheat, 96
Frost, formation of, 94
" how to foretell, 188, 189
" places most likely, 95
" prevention of, 94
" temperature for, 94
" value of, 190
Fruit, temperature for shipping, storing, etc., 290, 320

GASSES, 1, 43, 62
" carbonic acid, 7

HAIL, 91, 141
" conditions for, 91, 92
" formation of, 91
" largest, 92
" vortex, 92
Halos, 109, 110
" cause of, 109
" color and size, 109
" indication, 110
Haze, 101, 102
Heat of the day, 42
" radiation of, 42
" unequal distribution of, 53, 54
High and low pressure dividing line, 169

High pressure areas, 124 to 130
High pressure areas, birthplace of, 126
High pressure areas, distribution of dry air, 129, 130
High pressure areas, dryness of, 128, 129
High pressure areas, intense, 126
High pressure areas, paths of, 127
High pressure areas, temperature of, 128
High pressure areas, velocity of, 126, 127
Hot winds of Texas, 58
Humidity, 23, 24, 65, 66
" absolute, 24, 65
" highest and lowest, 68
Humidity, how measured, 24
" percentage of, 24
" places of greatest and least, 67, 68
Humidity, relative, 24, 65, 66
Hurricanes, 130 to 135
" attended by rain, thunder and lightning, 135
Hurricanes, conditions preceding, 133, 134, 135
Hurricanes, development of, 130, 131
Hurricanes, diameter and force of, 132, 133
Hurricanes, different from cyclones, 130, 131
Hurricanes, formation of, 131
" paths of, 132
" progressive motion, 133
Hurricanes, season of, 131, 132
" West Indian, 167, 168

Ice, formation of in streams and rivers, 51
Ice, thickness of, 51
Indian Summer, 72
Instruments, 9

Light, absorption of, 100, 101
" colors of, 99, 100, 101
" diffusion of, 98, 100
" dispersion of, 103
" rays of, 100
" reflected, 8, 98, 99, 100, 102, 103, 104
Light, reflectors of, 100, 101
" refraction of, 98, 99, 100, 102, 103, 104
Lights, northern, 108, 109
" southern, 108, 109
Lightning, 106, 141
" ball, 107
" classification of, 107
" flash, 106
" heat, 107
" positive and negative, 106
Lightning, rate of travel, 107
" sheet, 107
" with hurricanes, 135
Lightning, zigzag, 107
Liquids, 62
Local storms, 137 to 152
" weather conditions in making forecasts, 169, 237 to 264
Low and high pressure dividing line, 166
Low pressure areas, 112 to 123, 159

Maps, comparison of, 170
Mercury, boiling point, 19
" column of, 10
" expansion of, 19
" freezing point, 19
Meteorology, 1
" teaching in schools, 320 to 338
Microbes, 7

Mirage, cause of, 102, 103
Mock sums, 110
Moisture, 62

NITROGEN, 1
Northern lights, 108
Northers, 58, 59

OCEAN BREEZES, 56, 57
Optical phenomena, 102
Oxygen, 1, 7
Ozone, 2

PLANTS, decay of, 101
" why green, 101
Polymeter, 26, 27, 279, 283
" where purchased, 26
Pressure and altitude, 38,
" distribution of, 113, 114
Pressure, gradient, 114
" gradient and corresponding wind velocities, 114, 115
Pressure, gradient, steepest, 116
" of the air, 36, 37
" range of, at sea level, 38
Pressure, table of elevations, 38
" unequal distribution of, 37
Pressure, variation of, 36
Proverbs, weather, 274 to 279

RADIATION OF HEAT, 42
Rain, 27, 79, 141
Rainbows, 103, 104, 105
" colors of, 103, 104, 105
Rainbows, moonlight, 105
" when and how formed, 103, 104, 105
Rainfall, amount, 177
" annual, 81, 82
" daily, 80
" distribution of, 81, 82
" everywhere, 84
Rainfall, heaviest, 82, 84, 85
" heavy, 79, 80, 82, 84, 85
Rainfall, hourly fluctuation at N. Y. City, 83
Rainfall, hours of, 85
" how measured, 28
" in advance of storm centre, 176, 177
Rainfall, path of, 121
" typical annual fluctuations, 86
Rainfall, quantity of, 121
" when likely, 175, 176, 177
Rainfall, with cyclones, 121
" " hurricanes, 135
" gauges, 29, 30
" corresponding to weight, 346
Rainy days, number of, 85
Rooms, ventilation of, 7

SLEET, 90
" how formed, 90
Sky, blue, how caused, 101
Snow, colored, 90
" depth of, 88, 89
" districts of, 88
" line, 89, 90
" value of on ground, 283 to 290
Snow, white appearance, 90
Snowfall, 87, 88
" how measured, 31
" heavy, 89
Snowflakes, 87
Sound, rate of travel, 108
St. Elmo's fire, 108
Stars, twinkle of, 100
Storms, 111
" action of, 174, 175
" centre, 115
" movement of, 179
" classification of, 111, 112
Storms, combination of, 164
" force of, 118

Storms, forecasting of, 164 to 180
Storms, how caused, 111
" irregular movement of, 163, 164
Storms, movement of, 174 to 179
Storms, of autumn, 168
" of spring, 169
" of winter and summer, speed of, 167, 168
Storms, progressive and rotary movement, 119, 120
Sun, angle of, 41
Sun, blue, 103
" dogs, 110
" midnight, 338, 339
Sun, rays, 103
" red, 101
" setting, colors of, 101, 102
Sun, rise and sunset forecasting by clouds, 266 to 269
Sun, moon and stars, weather changes foretold by, 272, 273, 274
Suns, mock, 110
Sunshine, approximate hours of, 78

TABLE, wet and dry bulbs, hygrometer, 345
Temperature, 19, 40, 290 to 320, 342, 343, 344
Temperature, annual average, 44
Temperature, annual range of, 46
Temperature, average, 43, 44
Temperature, average daily mean, 340
Temperature, below zero, 49
" daily mean, 43, 44
Temperature, daily range of, 43
" decrease of with altitude, 50
Temperature, difference between extremes, 45
Temperature, extreme and sudden changes, 47
Temperature, freezing, 49
" greatest daily rise on record, 48
Temperature, greatest range in United States, 45
Temperature, highest daily range, 47
Temperature, injurious to food products, 290 to 320
Temperature, lines of, 179, 180
" loss or gain, to determine, 44, 45
Temperature, lowest and highest ever recorded, 45
Temperature, maximum, 49, 340
Temperature, minimum over United States, 48, 341
Temperature, monthly average, 44
Temperature of the earth, 52
" " " ocean, 51
" shipping of perishable goods, 290 to 320
Temperature, storing of perishable goods, 290 to 320
Tide table, 347
Time chart, 341
Thermometer, 10
" centigrade, 21, 22
" comparative scales, 20
Thermometer, difference between scales, 21, 22
Thermometer, dry and wet, 189
" Fahrenheit, 21, 22
Thermometer, maximum, 22, 23
Thermometer, mercurial, 19
" minimum, 22, 23
" scale, 20
" range of, 20
" Reaumur, 22
" spirit, 19

Thunder, 107, 108
" with hurricanes, 135
" storms, 144 to 152
" " areas, 147, 148
Thunder-storms, cause of, 145
" " conditions, 179, 180
Thunder-storms, conditions during, 150, 151
Thunder-storms, danger of, 151, 152
Thunder-storms, formation of, 145, 146, 147
Thunder-storms, lightning discharge and thunder, 150
Thunder-storms, movement and distribution of, 149, 150
Thunder-storms, relation to low pressure areas, 147, 148
Thunder-storms, two classes of, 148, 149
Tornadoes, 136 to 144
" conditions preceding, 138, 139
Tornadoes, difference in pressure, 142, 143
Tornadoes, dimensions and paths, 139, 140
Tornadoes, explosions in, cause of, 142
Tornadoes, formation of, 136, 137, 138, 179, 180
Tornadoes, hail, lightning and rain, 141
Tornadoes, progressive and rotary motion of, 140, 141
Tornadoes, reduced pressure, 142, 143
Tornadoes, states of frequency, 143, 144
Tornadoes, suggestions for safety, 144
Tornadoes, time of occurrence, 142
Trade winds, 54, 55
Typhoons, 130

VAPORS, 43, 62
Vegetation, decay of, 101
" why green, 101
Ventilation, 7
Vernal equinox, 40
Vision at sea, 8

WARM WAVES, 190 to 194
" " causes of, 190, 191, 192
Warm waves, east of Mississippi, 193
Warm waves, forecasting of, 194
Warm waves, west of Mississippi, 192, 193
Water, shallow and deep, freezing of, 51, 52
Water, vapor of, 1
Water-spouts, 152
Weather maps, 153 to 194
" " barometer lines, 155, 158
Weather maps, combination of storms, 164 to 166
Weather maps, development of low pressure storms, 159 to 163
Weather maps, disks and arrows, 156, 157
Weather maps, movement of low pressure storms, 159 to 169
Weather maps, outlining storms or areas of high and low pressure, 154, 155
Weather maps, practical forecasting by use of, 159
Weather maps, temperature lines, 156, 158
Werchsjansk, 45
Wind, circulation of, 54
" deflection of, 171 to 174
" direction of, 54
" force, 4
" movement daily, 33

Wind, places of highest velocity, 60, 61
Wind, pressure pounds per square foot, 4
Wind, pressure of, 3
" " scale, 6
" " table, 4, 5, 6
" to determine strength of, 166, 167
Wind, vane, 34
" velocities, 60
" velocity estimated, 6
" " hours, highest daily, 60
Wind, velocity, how measured, 31, 32, 33
Wind, velocity, months of greatest and least, 60
Winds, 53
" anti-trade, 55, 56
" Chinook, 58
" Fohn, 57, 58
" hot of California, 59
" least likely to be followed by rain, 252
Winds, most likely to be followed by rain, 251
Winds, prevailing east of the Mississippi, 59
Winds, surface, 56
" trade, 54, 55

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

AN INITIAL FINE OF 25 CENTS
WILL BE ASSESSED FOR FAILURE TO RETURN
THIS BOOK ON THE DATE DUE. THE PENALTY
WILL INCREASE TO 50 CENTS ON THE FOURTH
DAY AND TO $1.00 ON THE SEVENTH DAY
OVERDUE.

APR 15 1946
23May'54MC
MAY 9 1954 LU
23Oct'54BP
OCT 12 1954 LU
20Nov57HJ
REC'D LD
JAN 12 1958
DEC 20 1975 1 6
REC. CIR. DEC 4 '75

LD 21-100m-12,'43 (8796s)

TC 10823

116980

QC861
D9